W. B. No. 732.

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The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of contributions is not to be construed as official approval of the views expressed.

BACK NUMBERS OF THE REVIEW WANTED.

The Weather Bureau has not enough of the following numbers of the MONTHLY WEATHER REVIEW to meet even urgent requests for filling up files at institutions where the REVIEW is constantly being referred to. The return of any of these or of any 1919 or 1920 issues, especially November, 1919, will be greatly appreciated. The attached addressed franked slip may be used for this purpose, or one may be had on application to the Chief, U. S. Weather Bureau, Washington, D. C.

1914: January, February, March, April, September, October, December.
1915: May, June, July, August.
1916: January, August.
1917: June.
1918: February, September.
1919: Any issue, especially November.
1920: Any issue, especially January.
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MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

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JANUARY, 1921.

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THE METEOROLOGY OF THE TEMPERATE ZONE AND THE GENERAL ATMOSPHERIC CIRCULATION.[1]

Preliminary report by Prof. V. Bjerknes.

[Geofysisk Institut, Bergen, Norway, Apr. 30, 1920.]

SYNOPSIS.

The squall and steering lines of cyclones constitute, when considered together, a line of discontinuity north of which the air is characterized by low temperature, high visibility, dryness, and motion from east and north. South of the line the opposite of these characteristics is is the rule. The line of discontinuity, which can be traced for great distances, and, if observations were available, could probably be traced around the entire Northern Hemisphere, has been called the *polar-front line*, and may be regarded as the meeting place of polar and equatorial air.

Loops occasionally form in this line, with the result that masses of warm or cold air are separated from the parent masses. These loops and their results are somewhat dependent upon the latitude of the polar-front line. Such cutting off of air masses represents the formation of HIGHS and LOWS.

The weather of the Northern Hemisphere is the result of the advance and recession of the polar-front line. When the warm air extends farther north than usual, there is a tendency for an accumulation of cold air north of the line. When the pressure from this accumulation becomes sufficiently great, the cold air breaks through and flows southward, causing a change of the type of weather. Thus, the polar-front line is of great importance in forecasting, and, as observations are extended around the earth, it may assist in long-range forecasting.—*C. L. M.*

In Norway it has been tried from the year 1918 to base the forecasts of the weather on the application of a very close network of meteorological stations. The study of the corresponding *very detailed* synoptic charts has led to interesting results even for the large-scale meteorology. They are due especially to the three young meteorologists J. Bjerknes, H. Solberg, and T. Bergeron, who have been attached to this service, and who will return to the subject in detailed papers.

A very short summary of some of the main results will be given here. They will be seen to give to some extent, both verifications and further developments of ideas, which, although advanced by important theoretical meteorologists, have not yet exerted any noticeable influence upon the development of meteorology.[2]

The great changes of the weather in our latitudes have been found to depend upon the passage of a line of discontinuity, which marks the frontier between masses of air of different origin.

A line of this kind has first been stated to exist in every cyclone, which is not perfectly stationary. It here borders a tongue of warm air, which from an eastbound current penetrates into a westbound current of cold air (fig. 1). The whole system propagates with the eastbound current, and the cyclonic center with the lowest pressure is in the region where the cyclonic track touches the border of the tongue. The front border, before this point, is curved like a reversed S, the rear border, behind this point, has a uniform concave curvature. Along the front border warm air from the tongue ascends the barrier formed by the cold air. In return this cold air flows round the tongue in order to penetrate below the warm air along the rear border. Thereby two bands of rain are formed, a broad one in front of the tongue, where the warm air spontaneously climbs the cold, and a narrow one, generally called the squall line, along the rear border, where the advancing cold air violently lifts the warm air of the tongue.[3]

It has been found by use of the detailed maps, that the line of discontinuity continues even outside the

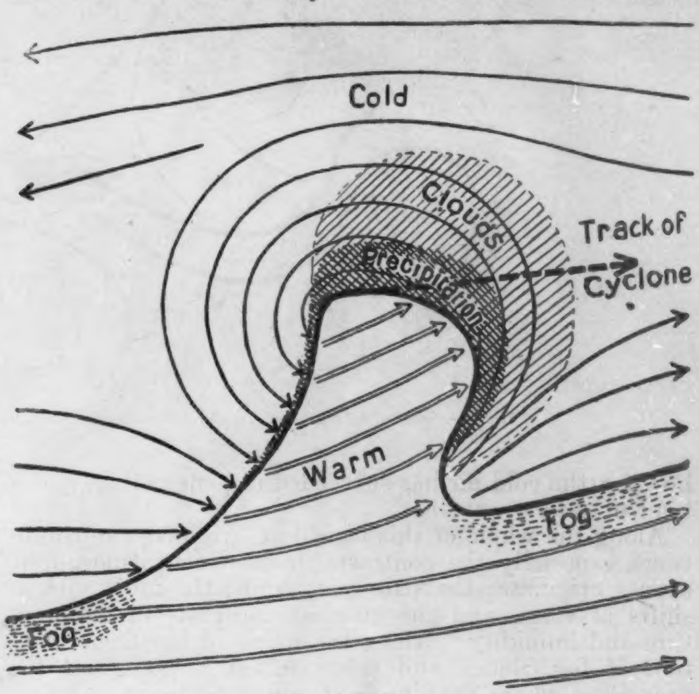

Fig. 1.—Cyclone.

cyclone, passing from the one cyclone to the other: They follow each other along a common line of discontinuity just as pearls on a string.

When one has got acquainted with all the signs, the direct and the indirect ones, which are seen to indicate the position of a line of discontinuity on the very detailed maps, it proves possible to discover them even on less detailed maps. Figure 2 shows roughly the course of such a line, December 31, 1906, as it may be drawn upon the Hoffmeyer maps of the Atlantic Ocean for that day.

[1] Published also in *Nature* (London), June 24, 1920, pp. 522-524.

[2] *Dove:* Das Gesetz der Stürme. Vierte Auflage. Berlin, 1873. *Helmholtz:* Über atmosphärische Bewegungen, Sitzungsberichte der K. Preuss. Akad. der Wissenschaften 1888, Meteorologische Zeitschrift, 1888. *Brillouin:* Vents Contigus et Nuages, Annales du Bureau Central Meteorologique, 1898. *Margules:* Energie der Stürme. Jahrbuch der K. K. Centralanstalt für Meteorologie. 1903, Anhang.

[3] *W. N. Shaw:* Forecasting Weather, p. 212. London, 1911. *J. Bjerknes:* On the Structure of Moving Cyclones. Geofysiske Publikationer, Kristiania, 1919; and Mo. Weather Rev., Feb., 1919, 47: 95-99.

When similar charts are drawn from day to day, as accurately as circumstances allow, a series of large-scale results very distinctly present themselves.

Though we have been able to draw the line only half round the pole, there can be no doubt that it surrounds the polar regions as a closed circuit. On the northern side of this line all signs indicate air of polar origin; It has a low temperature for the latitude, shows great dryness, distinguishes itself by great visibility, and has a prevailing motion from east and north. On the southern side of the line, the tropical origin of the air is recognized by the corresponding signs; its generally higher temperature, its greater humidity, its haziness, and its prevailing motion from west and south. There can then be no doubt concerning the origin of the line. Heavy cold air flows out along the ground from the polar regions. It is separated from the overlying warmer air by a surface of discontinuity, the height of which above the ground decreases very slowly until it cuts the ground along our line of discontinuity. Thus this line shows how far the cold air has succeeded in penetrating, it is a kind of *polar front-line*.

Along the whole of this front-line, we have the conditions, especially the contrasts, from which atmospheric events originate: the strongest winds, the most violent shifts of wind, and the greatest contrasts in temperature and humidity. Along the whole of the line formation of fog, clouds and precipitation is going on, fog prevailing where the line is stationary, clouds and precipitation where it is moving.

The line has a wavy form, and is in a continuous undulating motion, thereby sweeping over the whole of that zone which is called the temperate. The wavy form comes from alternately cold and warm tongues of air, which extend themselves toward Equator or pole. This whole system is propagating from the west to the east, while the line, at the same time, changes its form, especially when great masses of accumulated cold air are expelled from the central polar regions. The more wavy the form of the line, the more tempestuous and variable is the weather. At the northern ends of the warm tongues, the air motion which characterizes the cyclones is recognized, and the corresponding areas of rain are seen so far as it has been possible to mark them from the scarce observations: these are the places of the great storms and the low barometric pressure. The broad tongues of polar air, on the other hand, bring the clearing up between the successive storms and the corresponding higher barometric pressure.

Two expanding tongues of cold air may occasionally cut off from its base an interjacent tongue of warm air. Then the storm at the polar end is no more supplied by warm air, and it will soon lose its power: this is the death of a cyclone. A tongue of polar air, which has extended itself too much toward the Tropics, may be cut off in a similar way. Or, as the consequence of a new outbreak of polar air, a more retired front may be formed behind a too-far-advanced one. In this way great isolated isles of polar air are formed on lower latitudes; this gives the formation of the great anticyclones, which generally are known to bring steady good weather.

Thus the anticyclones are born in a similar way as the cyclones die. Cyclone and anticyclone and all meteorological events of the Temperate Zone are in the most intimate way related to the polar front and its motion.

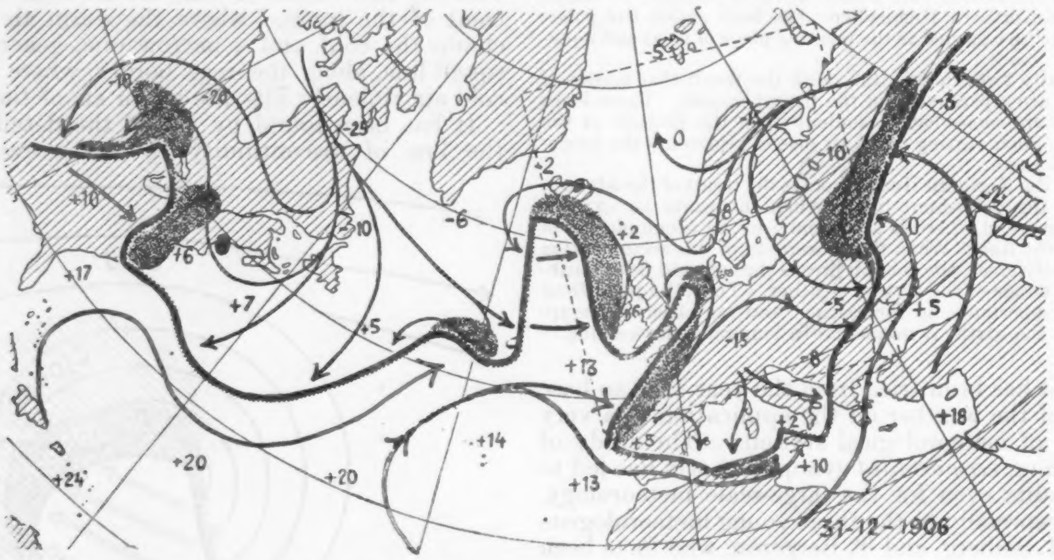

FIG. 2.—Front of polar air Dec. 31, 1906. The rainstorm which is occurring near the Great Lakes arrived at the coast of Norway on Jan. 5, 1907.

This expulsion of great masses of polar air, which leads to the formation of anticyclones, also enters as an essential element into the great atmospheric circulation. There is a practically continuous flow of warm air along the ground from the HIGHS of the subtropic calms toward the polar regions. This flow concentrates itself in the warm tongues and continues into the polar regions in upper levels. Here the air is cooled, and by and by reaches lower levels. Thus increasing masses of cooled air are accumulated behind the polar front. This must continuously advance with the effect that the tracks of the corresponding cyclones are always moved farther toward the south. Finally, at the place of the smallest resistance, great masses of cold air break through and are expelled in the direction of the Tropics. The polar front performs a corresponding retreat, the cyclonic tracks are again displaced to the north, and the type of weather is changed. Then the same play begins over again. This intermittent form of the great atmospheric circulation is especially pronounced in the winter. During the summer, the polar front is far retired, and

the high temperature of the continents exert a considerable influence. Then occasionally a continuous return of polar air may be established along the west coast of the continents and leading direct into the trade winds.

These results can not fail to exert a considerable influence upon the methods of weather forecasting. All meteorological events of the Temperate Zone, great and small, derive from the described great atmospheric circulation, as we know it from the motions of the polar front. If we succeed in watching it effectively, it should be possible to give the short-range forecasts a hitherto unattained accuracy. And it should be possible to complete them by long-range forecasts giving the general character of the weather perhaps for weeks ahead. And these two kinds of forecasts could be extended to all regions of the Temperate Zone, to oceans as well as to continents. The required survey of the polar front is merely a question of organization.

PROPAGATION OF COLD AIR ON THE SURFACE OF THE EARTH.[1]

By F. M. EXNER.

[Reprinted from *Science Abstracts*, Sect. A, Sept. 30, 1920, §1137.]

The general problem for solution is: Given a mass of dense air of known form and state of motion, covering a small region of the earth's surface, and bounded above and around by less dense air also in known state of motion, to determine the subsequent movement and changes of form of the dense air. The problem is solved for some particular cases in two dimensions, by the hydrodynamical methods applicable to waves at the surface between two fluids of unequal density, but the results sought are mainly qualitative. The dense air is taken initially in the form of a ridge of rectangular cross-section and infinite length. If both fluids are originally at rest, and friction and the earth's rotation are neglected, then the ridge breaks up into two of equal breadth and half the height of the original, traveling in opposite directions perpendicular to their length with a velocity proportional to the square root of the difference of absolute temperature between the cold and warm air. As the ridges move apart the warm air flows in and covers the region of the earth's surface between them. Introducing friction, the ridges separate as before, but decrease in height as they advance, the space between them remaining covered with cold air. In this case, too, the rear of each advancing ridge is higher than the front. On a rotating earth without friction the cold ridge, supposed streaming in the direction of its length, breaks up as before, but the ridge traveling to the left of the direction of streaming (Northern Hemisphere) increases in height, while the other decreases. The velocity of propagation is now greater than before, and the front of each ridge higher than the rear. If the warm air above is streaming at right angles to the ridges, it has the effect of checking the advance of one of them, and may, if strong enough, reverse its motion and make it slowly follow the other, which has its velocity of propagation increased. Other cases are obtained as combinations of these. A comparison is made with observations on the spreading of cold waves over Europe and North America. The author finds in this work an explanation of the phenomena exhibited on these occasions, and in particular of the observed fact that when cold air breaks through from the polar regions it first seeks to spread W. or SW., then S., SE., E., and often finally NE.—*M. A. G.*

[1] Akad. Wiss., Vienna, vol. 127, 2a, 1918, pp. 795-847.

THE ENERGY OF CYCLONES.

In several issues of *Nature* (London) late in 1920 there has appeared a running discussion of the source of the energy of cyclones. There is presented such a concise nontechnical summary of the present ideas of British meteorologists on this intricate subject that extensive quotations are reprinted here. The discussion was started by adverse criticism of Margules's theory by R. M. Deeley. In an obituary of Dr. Max Margules, published in *Nature* (London) October 28, 1920, pp. 286–287,[1] E. Gold gives the following short summary of Dr. Margules's discussion of the energy of storms:

> Margules contributed to the Year Book of the Meterological Institute of Vienna for 1903 a comprehensive discussion of the energy of storms. He showed that the atmospheric phenomena associated with storms would arise if two masses of air of different temperatures were in juxtaposition. The situation would be unstable, and in passing from this unstable situation to a stable one the potential energy would be reduced, part of it being converted into the kinetic energy of the ensuing "storm." This paper contains the germ of the theory of squalls, of the development of cyclones, of polar fronts, and so forth. It concludes computations of the horizontal velocities which would result from various distributions of pressure and temperature, and shows that actual distrib tions would lead to velocities of 50 miles an hour. Margules summed up his conclusions in the sentence: "So far as I can see, the source of storms is to be sought only in the potential energy of position."

Mr. Deeley, in a letter to *Nature* (Nov. 11 issue, p. 345), criticises many of Margules' points, and concludes with the following sentence:

> The facts seem to point to the stratosphere as being the main source of energy of storms and trade winds.

To this Lieut. Col. Gold replies (ibid.):

> Dr. Margules wrote his paper mainly in connection with phenomena of the line-squall type, but he realized that it might have wider applications, and later investigations do indicate that discontinuity of temperature is the prime factor in the "birth" of cyclones. If one had an atmosphere with uniform pressure at sea level, but with masses of warm and cold air, then at 9 kilometer pressure would necessarily be low in the mass of cold air, and a cyclonic circulation would ensue; but the enrgy of motion would be derived from the potential energy of the initial state.
>
> Differences of temperature originate in the lower atmosphere. The stratosphere may be able to draw upon a source of energy of which we are ignorant; it can not of itself provide the energy of storms.

In the next issue of *Nature* (Nov. 18, pp. 375–376), W. H. Dines presents the following further discussion:

> It does not seem to me as though any really satisfactory theory has yet been put forward to explain the genesis and maintenance of cyclones; I fully agree with Mr. Deeley (Nov. 11, p. 345) that they are not due to contiguous masses of air at different temperatures but, on the other hand, I do not see how they can originate in an inert and stable region like the stratosphere.
>
> Were storms produced by contrasts of temperature—or in other words, by the so-called polar front—surely they would be most violent where the contrast was most marked. The stormiest parts of the world are the great belt of the southern ocean from 40° to 60° S. latitude, and that part of the Atlantic which lies northwest of Scotland, and neither of these regions shows any exceptionally steep gradient of temperature.
>
> Observations in the upper air have shown a remarkable uniformity in the mean temperature (mean with regard to height) from 0 to 20 kilometers in every place where they have been obtained, and it follows as a corollary that there is a very uniform pressure at 20 kilometers height over the globe, for the pressure at 20 kilometers is almost independent of the surface pressure. Observations over Europe, the only part of the world where they are numerous enough for the purpose, have also shown a most extraordinarily close correlation between the temperature and pressure of the air in the upper part of the troposphere,

[1] Abstract published in *Mo. Weather Rev.*, Oct., 1920, 48:601.

many of the coefficients exceeding 0.90. These facts must be reckoned with in any theory about the formation of cyclones.

My own belief is that pressure differences originate in the upper half of the troposphere from variations in the strength of surrounding winds. Being given the means of originating and maintaining a difference of pressure at about the height of 9 kilometers the rest of the phenomena would follow readily. The distribution of temperature, the high positive correlation below and the negative correlation above, and the rise and fall of the tropopause between cyclone and anticyclone are all explained by the vertical motion of the air that would naturally follow from the distribution of pressure.

A short note by Sir Oliver Lodge followed (Nov. 25, p. 407):

I do not find that people in general are aware of an important source of energy for the maintenance and intensification of cyclones, nor am I acquainted with a clear exposition by a meteorologist that the condensation of aqueous vapor will suffice.

Atmospheric pressure being a ton per square foot, the disappearance or collapse of a cubic foot of ordinary air would yield a foot-ton of work. The disappearance, by complete condensation, of the aqueous vapor in 760/12.7, say 60, cubic feet of atmosphere would yield about the same amount.

If, then, the temperature of saturated air fell from 18° to 12° C. by reason of condensation and rainfall, so that the vapor pressure diminished from 15.36 to 10.46 millimeter of mercury, a foot-ton would be generated in each 155 cubic feet of that region of the atmosphere. Incidentally, the corresponding deposit of liquid would be 5 grams per cubic meter, or a rainfall of one-third inch from a vertical mile of air.

Assuming that the above fall of temperature in the central region of a traveling cyclone is not excessive, the energy available in each cubic mile of it would be nearly a thousand million foot-tons.

Immediately following this is a note by J. R. Cotter suggesting "that the energy of a cyclone is derived from the heat energy of the earth's surface." Sir Napier Shaw, Harold Jeffreys, and L. C. W. Bonacina contributed further to the discussion in the issue of December 2 (pp. 436–438):

There can be no doubt, I suppose, that solar and terrestrial radiation are ultimately responsible for the kinetic energy of the winds. The doubts expressed by Mr. R. M. Deeley in *Nature* of November 11 and by Mr. W. H. Dines in the issue of November 18 can refer only to the details of the phenomena consequent on the process of transformation of the energy. The first stage is obviously the storage of energy in the potential form of air charged with heat and moisture at the surface or lower levels and cooled by radiation at high levels, especially in the polar regions, as on the plateau of Greenland or on that of the Antarctic continent, or on the sunless slopes of the Himalaya. Equally without doubt the next step is convection, the greater part of which is indicated here and there by falling rain or snow. Measurements of rainfall assure us that there is no lack of energy available for violent winds if the heat engine is at all efficient.

The general effect of the process of convection is the development of a vast circulation in the upper regions of the atmosphere from west to east round the poles, which has its counterpart in the normal distribution of pressure at corresponding levels. That is probably most pronounced at a level of 8 kilometers because at that level density is equal all over the globe at all seasons of the year. Above that level, up to the level of equal pressure at 20 kilometers of which Mr. Dines writes, there is, on the average, a gradient of density from the Equator to the pole, and below the level of 8 kilometers a gradient of density in the opposite direction. The layer of maximum average velocity is above the layer of maximum pressure gradient on account of the diminution of density with height.

Below the level of 8 kilometers the distribution of pressure is affected by the gradient of density in a very irregular manner, because the distribution of land and water is irregular. The net result at the surface is the complicated distribution of average pressure which we find in the maps of normals for sea-level.

The maintenance of the average general circulation from west to east in the higher levels is due to the gradual convergence toward the polar areas from which the cooled air flows. That must obviously be balanced by a corresponding flow toward the Equator, and as poleward flowing entails a westerly circulation, so flowing toward the Equator entails an easterly one. We must, therefore, find room in the system for a body of air flowing from the east comparable at least with the circulation from the west. We find such a body of air in the great easterly circulation of the intertropical regions, which is naturally stowed away over the Equator as far as possible from the centers of the two polar demi-hemispheres of influence of pressure gradient.

These great circulations, easterly and westerly, form a normal "groundwork" of all atmospheric motion; and when Mr. Deeley and Mr. Dines write of the energy of cyclones, they are not concerned, I think, with the energy of the general circulation of the upper levels which I have described, but with the minor circulations which represent the perturbations of the major circulation.

I think myself that the convection of warm, moist air, combined with the vagaries of temperature in the lower layers, will, in the end, prove to be sufficient to explain the energy of cyclonic air currents—whether directly or as the secondary effect of current-differences, I can not say. Probably, in order to get a correct view of the perturbations, we ought to subtract vectorially from the observed winds the local motion of the normal circulation, or else accustom ourselves more than we do to the theoretical combination of local circulation with a general circulation.

There are four other aspects of the problem upon which we are at present almost uninformed. The first is the locality where the cyclone, which is the subject of study, was generated; just as the cyclone itself is a perturbation of the general circulation, so what we see going on over our heads is the perturbation of a cyclone which may have originated in the general circulation thousands of miles away. A cyclone is a more or less stable dynamical system which certainly travels, but changes as it travels. The second aspect is the variation of velocity of the wind with height in the general circulation and in the cyclonic area itself. The third, which is closely connected with the second, is the trajectory of convected air. This could be calculated if we knew the point from which it started and the variation with height of the current which carried it. One often reads of convected air rising vertically, but we know that the actual trajectories of a pilot balloon are of very various shapes, seldom vertical, and the balloon may part company from the air which supported it at the start by a distance measured in tens of kilometers. Air in convection rises very slowly. If we set its vertical velocity at one-hundredth of that of a pilot balloon, the convected air may be thousands of kilometers from the starting point before its upward journey is finished, and its path may be very complicated. It is possible that this conception of the slow, gradual ascent of air may have a bearing upon the cloud formation associated with a coming cyclone, but the subject is too long for a letter.

The fourth aspect is the behavior of the convected air with regard to its environment. The slowness of its rate of ascent is dependent largely upon the development of eddies and consequent dilution of its mass with the cooler environments. This can not of itself arrest the upward motion, though it delays it, and, consequently, when the convected air has arrived at its ultimate level it will have carried with it some of the air which formed its environment on the way. Hence the rising air will have "evicted" a certain amount of air by its passage.

The importance of combining these aspects is at once apparent if we consider that convection in still air would simply mean a readjustment of the mass in the vertical. The potentially warm air would be at the top instead of at the bottom, and the effect of a completed process of convection would be that pressure would rise within the area of operations. But if the risen air were delivered into a rapidly moving current at the top, the air which it had "evicted" from the environment on its way would be lost to the column, and when the process was completed the air would close in from the top, the bottom, and the sides. If there were any relative motion to begin with—and there is always some—closing in from the sides must develop cyclonic circulation with a cold core. Closing in from the bottom with air colder and drier than that which began the convection would stop on account of dynamical cooling, and closing in from the top means the settling down of the air of the stratosphere and a consequent low tropopause with a column of air above it warmer than its environment.

These conditions describe what the late Lord Rayleigh postulated for superposing a vortex on a current with relative velocity of its parts. They also agree with what Mr. Dines describes as the results of his examination of actual cyclonic conditions in England. And this view of the procedure is borne out by the examination of tropical cyclones. We can form legitimate inferences from the pressure records of these visitations because the normal conditions of the localities where they occur are extremely regular. We can see by an inspection of the graph of pressure that the region covered by a cyclone has simply lost a certain part of the air which it normally possesses. In one example I estimated the loss as equivalent to 40,000 cubic kilometers at sea level. Beyond all doubt or question air had gone; it was not piled up in anticyclones fore and aft, as we used to think the convected air of our cyclones must be; it was gone clean away. I suspect that it travelled away in some upper current until slowed down over the tropical anticyclone of some ocean. The story will not be complete until that surmise is verified or the correct account substituted. Hence, for the time being, I am as curious about the life history of convective air currents as I was twenty years ago about that of surface air currents.

In any case, it seems to me certain that, because it carries away part of the air which it meets on its path, convection, wherever it occurs, must entail convergence, and therefore, except at the equator, it must give rise to a cyclonic circulation which may be transient, or, if circumstances are favorable, permanent. The function of the

stratosphere seems to be not constructive, but conservative and registrative. It protects the energy from being dissipated by "filling up," because the descent of its isothermal air is arrested by the adiabatic rise of temperature. That is, indeed, the common function of all "decks" or lids in the atmosphere, of which the stratosphere is the chief. At the same time, for an observer the stratosphere registers the locality of low pressure by the lowness of the tropopause and the relative warmth of the air column above it. It seems to be a law for the general circulation and for local circulations that as pressure diminishes in the troposphere the tropopause is lowered and the temperature of the columns above it rises.

Consequently, my view at the present time is that the energy of a cyclone is due originally to convection in a region with a suitable law of variation of velocity with height; it is guarded at the top by the isothermal condition of the stratosphere, and on the sides by the balance of pressure and rotation. It is open to slow attack at the bottom on account of the friction of its winds with the surface, and unless its energy can be maintained by additional convection it must perish. I do not think that a traveling cyclone carries its supply of rain for long distances; it probably manufactures it out of the material in the lowest levels which it has to pass over. But it uses the energy so supplied first to form a secondary, and afterwards to absorb it or to be absorbed by it.—*Napier Shaw.*

It is a well-known hydrodynamical result that, in the absence of any external stabilizing influence, any surface of discontinuity of velocity in a fluid must be unstable. The effect of this instability is seen in the eddies produced in a mill pond, at the margin of the entering stream. A sufficiently rapid shearing, without actual discontinuity, will produce the same effect. Most atmospheric eddies are developed in this way. In the case of differences of velocity between different masses of air at the same level, gravity is not directly available to damp any eddies that may be produced, and hence it does not seem likely to be difficult to account for eddies with their axes vertical.

Thus the origin of cyclones may well be explained on the lines suggested in Mr. W. H. Dines's letter in *Nature* of November 18. It is rather more difficult to see what determines the size and intensity to which they grow. Ground friction must play its part; also, where the warm stream on the south side bulges northward, it must do so to some extent over the top of the cold air already there, and this arrangement makes for stability, and when sufficiently developed must prevent the further growth of the disturbance.

The speed of translation of the cyclone on this theory should be the mean of the velocities of the two currents, which is usually about correct. The geostrophic condition must also hold approximately, otherwise the disturbance would spread out with nearly the velocity of sound and disappear. What is not easy to see, however, is why the isobars tend to become more or less circular instead of wavy.—*Harold Jeffreys.*

I should like to express my agreement with Mr. W. H. Dines's view (*Nature*, Nov. 18, p. 375) regarding the origin of the initial difference of pressure which leads to the development, under the influence of the earth's rotation, of cyclonic circulation, and to state that I have often suggested that this initial disturbance may have a mechanical origin (see Quart. Journ. Roy. Meteor. Soc., vol. xliii, 1917, p. 27). At the same time it seems that one can not, on many grounds, ignore the effect of temperature contracts as a contributing factor in the further development and maintenance of storm energy.

To take the very fact which Mr. Dines cites, namely, the exceptional storminess of the Atlantic to the northwest of Scotland. This region is, in a most conspicuous degree, stormier in the winter months than in the summer, and it is almost one of the canons of physical geography that the excessive development of storm energy during the cold season is favored by the great contrast in temperature between the frost-bound continents and the warm Atlantic, the individual cyclonic systems breeding not so actively over the land areas, where the general pressure is high, as over the oceanic areas, where the general pressure is low. On the other hand, during the warm season—when the temperature gradient between the oceans and the continents is reversed, but is much less steep than the winter gradient—cyclonic energy in the North Atlantic is far less powerful, while over the sun-heated continents storm energy takes the form, not of extensive wind systems, but of localized convectional thunder systems. Furthermore, in the southern ocean, between 40° and 60° S., where there are no disturbing land masses, there does not appear, judging from the reports of navigators, to be such conspicuous seasonal difference in storminess, and this is borne out by statistics available for the Falkland Islands (Meteor. Office Geophys. Mem., No. 15).—*L. C. W. Bonacina.*

A rebuttal by Mr. Deeley is published in *Nature*, December 16, 1920, page 502, and adverse comment on it by W. H. Dines in the issue for December 23, page 534. The second paragraph of Mr. Dines's letter relates to the earlier comments of Sir Oliver Lodge:

> The point mentioned by Sir Oliver Lodge in his letter in *Nature* of November 25, has been, I think, put forward by von Bezold and others, but Sir Oliver seems to have overlooked the result of the heat set free by the condensation of the vapor. Could a cubic meter of damp air be confined in an adiabatic but extensible balloon and the vapor be condensed by any means, the result would be an increase of volume, for the expansion due to the heat produced by the condensation would far more than balance the contraction due to loss of pressure. If, indeed, the heat energy due to the latent heat of vapor all took the form of kinetic energy in the atmosphere, quite a trifling rainfall would suffice to produce over the same area the most violent cyclone ever recorded.

Prof. Alexander McAdie having become particularly interested in Sir Napier Shaw's discussion, wrote to him and obtained further comments. At the close of a discussion [2] of Shaw's published letter (quoted above), Prof. McAdie says:

> Finally, one further proposition appears to Shaw to be worth study, namely, that "an anticyclone is a region of descending air if the month is the unit of time; but if the unit of time is the hour or day, an anticyclone is simply an unchanging mass except for the outflow at the bottom." This outflow he has calculated (in a letter to the writer) as a settlement at the rate of 100 meters per day, about 0.7 m/s. In a cyclone per contra, the air rises at such a rate that the hour and the day are units of time.
>
> This conception of the time factor is novel, and if we permit its introduction, as it seems we must, then we are faced with the further problem of determining the life histories of slow-moving anticyclonic air descending from heights of 8 or 10 kilometers, most leisurely, requiring 6, 8, or 10 days to make the downward passage and landing far, far away from the place of setting out. In the case of hyperbars [large subpermanent high-pressure areas], such as the Atlantic [or Azores] anticyclone, Shaw says: "The out curvature is everywhere *the same angle;* and the velocity is proportional to the distance from the center. If $V=Cr$ and the velocity normal to the circle is proportional to r, the outward velocity will be $C'r$ and hence the outflow $\alpha 2\pi r^2$ is proportional to the area; and therefore implies a uniform settlement all over the area."

Much more will be said about cyclones and anticlones and the general circulation of the atmosphere when we have free-air data from more than a few small sections of the vast regions traversed by moving low and high pressure areas.—*C. F. B.*

THE RAPID FALL IN TEMPERATURE OF COLD WAVES.

A high pressure area will sometimes form over night, especially in or over the Lake region, where the temperature the day before was about normal for the season all over the district. Immediately the temperature falls with the accompanying northerly winds perhaps 20° or even 40° [F.] in 12 or more hours. This is quite a common occurrence in this section [northern New York] in the winter. This air could not have had time to lose so much heat by *radiation*, neither could the wind at the surface have had time to *import* so low a temperature. There are many clear nights with high barometer, with every opportunity for radiation to cause a big drop in temperature, but no such fall is observed other than perhaps 10° F. Last night [Jan. 26–27, 1921] under a clear sky and high pressure the temperature actually rose several degrees and without wind movement. A perfect calm prevailed. Where did this heat come from? For two nights before this, while under the influence of the northerly wind area, and only a fresh to light wind at that, the temperature rose but little during the day and fell during the night more than it would under ordinary conditions. * * * This coldness of the air does not feel as if it were due to long brooding or stagnation over cold

[2] Presented (by title) before the American Meteorological Society at Chicago, Ill., Dec. 29, 1920. Abstract published in *Bull. Am. Metl. Soc.*, March, 1921, 2: 40.

surfaces, it has a clean, fresh feel. Then again, in this area of northerly winds, as a rule, how clear the sky is!

In the summer this same condition is present, only, of course, greatly modified and masked by the great power of the sun. Here we have a clear sky and radiation from the sun supreme with every chance for high temperature, but the northerly winds keep the temperature down and but little rise occurs. Under the same conditions and southerly winds a "scorcher" would have been the result. * * *

As a rule * * * as long as the HIGH keeps its form and activity, there is a stationary or falling temperature within this area.—*Douglas F. Manning.*

DISCUSSION.

The "formation" of a HIGH and a big fall in temperature are coincident phenomena, since it is the arrival of an appreciable layer of cold dense air ousting warmer and therefore less dense air that makes the pressure rise so. When a HIGH appears without any change in temperature at the surface having occurred, a considerable body of cold air *must* have arrived aloft. For example, a fall of 5° C. at 500 meters altitude, 10° at 1,000 meters, and 10° at 1,500 meters would increase the density of this layer of air sufficiently to raise the surface pressure about 5 millibars (0.15 inch). Such a fall in temperature aloft would be possible without effect on the surface temperature if at first, as is commonly the case before cold waves in winter, the temperatures up to 1,500 meters were no lower than at the surface. Conversely, at the end of the cold wind, when a warm one sets in aloft, there may be no surface wind or other visible reason for a change, but the pressure will fall, and the air temperature at the surface may rise by the receipt of heat radiated from the warmer wind not far aloft.

Let us consider how the surface air temperature can fall so much faster than radiation, and transportation along the surface, could reduce it. After the temperature at 1 kilometer above the surface has fallen to 10° C. colder than that at the surface any further fall will be accompanied by a convectional interchange and an equal fall in temperature at the surface, the upper wind descending in a sudden gusts and routing upward the masses of warmer air near the surface. The temperature of the wind when it reaches the surface will be about 10° C. higher than when it started down from 1 kilometer. Nevertheless, its temperature will be lower than that which prevailed immediately before the gust arrived from aloft; otherwise it would not have come down. If the surface wind is 15 miles an hour that at 1 kilometer is likely to be 30 miles an hour, although its component from the direction of the surface wind may not be more than 25 miles an hour. This being the case, if the surface wind would in the course of the night lower the temperature at a place 5° C. merely by transportation along the surface, the fall to be expected would be nearly 5° more because of the wind aloft. Stronger winds and radiation from a snow surface into a clear sky at night would make extreme falls in temperature. Therefore, in forecasting the temperature change in a cold wave, the probable transportation of cold air at a moderate height is of more importance than that along the surface.—*Charles F. Brooks.*

BALLOON RACING—A GAME OF PRACTICAL METEOROLOGY.

By RALPH H. UPSON, Consulting Aeronautical Engineer.

[22 E. 17th St., New York City, Feb. 25, 1921.]

Transportation has always been more or less influenced by the weather. During the last 50 years, this influence has been somewhat lessened by the increasing use of automotive vehicles. Now, however, the advent of commercial air navigation makes weather more of a factor than it has ever been before, so much so indeed that the success of aircraft for commercial use will almost depend on how far the design progress can be paralleled by developments in three-dimensional meteorology. Now the question is: How can we best study this very important factor of weather in its application to aeronautics? Meteorology is no more an exact science than medicine is. To be sure, there *are* laws and principles that can be implicitly relied upon, but the great bulk of our future development for some time to come must depend on the accumulation and coordination of plain *facts experience*, and *practice*. The performance of any aircraft (whether heavier- or lighter-than-air) is a resultant of two factors: (*a*) The power plant of the craft, and (*b*) the surrounding air, or broadly speaking—the weather. Quantitatively, the effect of the weather is usually unchanged by a difference of speed and maneuverability of the aircraft. For example, a 20-mile side wind blows an airplane or airship sideways at just 20 miles per hour regardless of its speed of advance.

As in other branches of science, the best way to study this important subject from a practical standpoint is to separate it as far as possible from outside influences which only disturb the observations and confuse the result. The free balloon is almost ideally suited to our present purpose for the following reasons:

1. Having no motor, its control is entirely dependent on coordination with existing weather conditions. The performance of a balloon is exactly like that of a free particle of air with the addition of altitude control.

2. The entire freedom from pitching, vibration, noise and wind, permits the most delicate observations to be made.

3. Its simplicity and safety of operation makes a balloon especially desirable for a great variety of experiments. A free balloon is so safe that it is *practically* fool proof. It would take considerably more than an *ordinary* fool to hurt himself in one.

The progress in other branches of aeronautics has if anything increased the value of the free balloon for training. During the war all our airship pilots and a large proportion of our kite-balloon observers received preliminary training by free balloon. For training in navigation and meteorology it has also been advocated for airplane pilots. But its greater and broader value lies in the general stimulus to meteorological knowledge to be gained by its development as a recognized sport. And it is in no disparagement of its scientific and practical importance to say that as a sport, ballooning is the finest that can be imagined. It is also very moderate in cost. Recent developments in fabric and gas generators put ballooning within reach, financially and otherwise, of any moderate-sized club.

The *safe* piloting of a free balloon is easily and quickly learned. There are only two controls, ballast and gas. To go up or stop coming down, throw out ballast. To come down or stop going up, let out gas. The control of altitude and with it the choice of the desired wind cur-

rents depends only on the proper expenditure of ballast and gas.

Ordinary flights usually last from one to twelve hours, the landing being planned for a time and place that will best suit the convenience of the passengers. But prearranged plans are seldom entirely fulfilled. To realize them the pilot must constantly match his wits and skill against the prevailing wind conditions, which are never twice the same. An interesting story, as well as a scientific treatise could be written about every balloon flight that was ever made.

The highest art of ballooning finds expression in the national and international races for distance which are held every year. These commonly run anywhere from 400 to 1,200 miles distance and 18 to 60 hours duration. Having been a loser myself in the last big race, I need not be at all bashful to say that one of these races will draw on almost every talent that a man has—knowledge of navigation and meteorology, experience in its application, ability to size up the actual conditions, good judgment in their interpretation, practical skill in handling the balloon, firmness in adhering to a good plan of action but always with eyes and mind open for a better one, courage or caution where necessary, and plenty of plain physical endurance without forgetting good sportsmanship: these are a few of the qualities one can use to advantage in a balloon race. Of the nine international races for the Gordon-Bennett cup since 1906, Belgium has been winner once, France once, Switzerland once, Germany twice, and the United States four times. This year the races will start from Belgium because of the Belgian lieutenant, de Muyter's, great victory last year.

Our most immediate concern now is to see that America is well represented in this year's race. We are allowed a total of three teams consisting of pilot and aid for the three different balloons, each nation being limited to the same number. The only way to organize is to organize for a purpose, the only purpose in this case being to bring back to this country the famous Gordon-Bennett trophy. The different component parts of the plan must include attention to the following:

1. *Financing the expedition* is outside the scope of the present article, but it may be remarked that America in the past years has never failed to have representatives in this race.

2. *Equipment* is relatively unimportant, the only real necessity being a fairly tight envelope and good instruments. A racing balloon it should be noted is a much cheaper proposition than either a racing yacht or an airplane. There are probably at least a dozen balloons in this country which would be satisfactory to use.

3. *Personnel* is the most important item of all. We have an unusually rich choice now, owing to the interest of the Army and Navy in free ballooning, with all the pilots who were trained during the war.

The history of balloon racing up to the present time shows conclusively that it is taking on more and more of a meteorological character. In the past, races have been occasionally won by mere practical skill in operation of the balloon, but the time when this is possible is rapidly passing, if indeed it has not already passed. In the future, meteorological knowledge instead of being a secondary factor in the assets of a team, will be absolutely the controlling factor.

The record of the race from Birmingham, Ala., last fall is a very interesting study in this connection. The winner was a trained meteorologist[1] besides being a good balloon pilot. His performance in that race sounds almost incredible, but the facts can not be avoided. He, the winner, among all those who really stayed in the race, landed the very earliest. All started from Birmingham, Ala., between 5:30 and 6 p. m., October 23. At 9:30 a. m. of October 25 the winner was landing in the State of Vermont, while most of the other balloons were floating gently over Indiana and Michigan. One of these (we need not mention names) had ballast in plenty for another 24 hours, but would have needed twice that length of time to reach the distance marked off by the winner. An altitude of up to more than 20,000 feet was tried without success, the experiment at that time only serving to exhaust the ballast supply. At 2 o'clock in the afternoon (of the third day) a landing was finally made near Detroit, at approximately the same spot where the winner had passed over about 16 hours before.

These are striking coincidences, it must be admitted, but there is plenty of other evidence at least as strong showing the great importance of meteorology in modern balloon racing. And the shoe fits both ways. Not only does balloon racing need meteorologists for its best development, but meteorologists need the experience and stimulus which free ballooning is best able to give.

Ballooning is by all odds the best practical training for anyone who would use weather knowledge. Then why not for professional meteorologists? To be perfectly frank, ballooning is no longer important for the making of structural experiments from an engineering standpoint. The more definitely practical types of aircraft, such as airships and kite balloons, have reached a point where they are no longer dependent on free balloon experience for their structural requirements. But the keen struggle of wits against weather and the wonderful spirit of adventure which is an intimate part of even the shortest balloon flight, will always keep alive this fine sport. It is not given to most of us in these modern days to make voyages of exploration to unknown parts of the globe, but this spirit of adventure and exploration is still alive in human hearts and it is to this that free ballooning makes its great appeal, thus increasing and extending the value of its scientific service.

The recent unintentional flight of a Navy balloon to Hudson Bay has furnished striking proof of how people will respond to anything that stirs this spirit. But there is one unfortunate thing about ballooning from a standpoint of the general public. It is hard for spectators to see anything more of a race than the start. Hence, there is more than the usual importance to be placed on consistent development and interpretation by those who are naturally the nearest to it. We must get away from false leads and put ballooning where it belongs, squarely on the basis of sport and meteorology.

To meteorologists in particular, I would say: "Take your child. It is yours to develop and to bring out its great possibilities. In your hands and with your guidance this wonderful sport will be preserved with added value for future generations, and there is nothing that will be of more real help to aeronautic development in general."

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[1] A personal account of Lieut. De Muyter's experiences in this race is given in *L'Aérophile*, Dec. 1-15, 1920, pp. 366-367, under the title, "How I won the Gordon-Bennett cup."—EDITOR.

METEOROLOGICAL ASPECTS OF THE INTERNATIONAL BALLOON RACE OF 1920.

By C. G. ANDRUS, Observer.

[Weather Bureau, Due West, S. C., Feb. 24, 1921.]

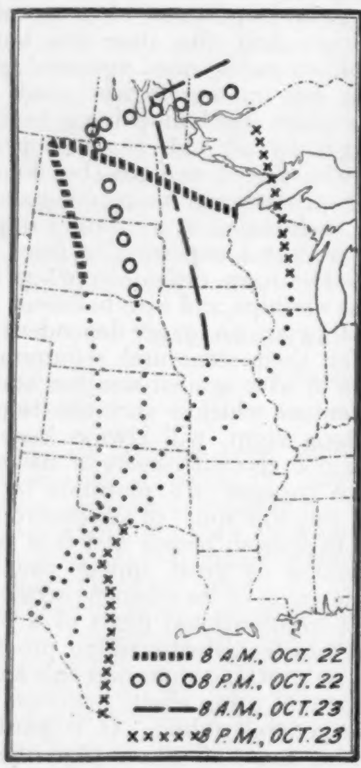
SYNOPSIS.

Successful free-ballooning depends on meteorology, and especially on the study of free-air conditions. The International Balloon Race from Birmingham, Ala., October 23, 1920, was the first occasion of its kind in this country where meteorological upper air and surface reports were made available to the pilots and where assistance was provided to guide them in the interpretation and use of the telegraphic reports which the Weather Bureau supplied from the eastern and central United States. It is clear that more extensive free-air observations are necessary. Advices and up-to-the-minute data were of unusual value in this race, owing to the complex atmospheric conditions, which demanded a cautious nicety of control by the aeronauts. Conditions were not unfavorable at the surface, and were nearly normal in the free air. An analysis of the cyclonic conditions has been made in terms of the Bjerknes hypothesis of stream lines, and the application of this method explains the peculiarities encountered by the balloonists.

Explicit forecasts were made for the race. These were right, and the winning teams were those who followed closely the course mapped out by the Weather Bureau. Not merely the horizontal currents of the atmosphere but also the thermal activity and the radiation, condensation and equilibrium values must be given due consideration in the modern aerial weather forecasts for free ballooning. Likewise, efficiency on the part of the aeronauts demands that they make the greatest use and allowance for the weather factor. Aerial transport of every character will do well to study this weather factor in order to promote greater efficiency.

Meteorology is the key to successful free-ballooning. To meteorology and its newest branch, aerology, the pilots of free-balloons must turn to solve the problems of the location and condition of their courses in the free air; the racing balloonist seeks the factors of greatest speed and longest fetch of the winds of the lower levels; the balloonist trying for a destination seeks the factors of direction; the reconnaissance balloonist seeks the elements of quiet and safety. Of the great sporting events of the world the International Balloon Races are among the most famous; the men attracted to partake in them are distinguished for daring and ability. In the last four years the study of upper-air conditions has taken such strides that to-day, without the intelligent use of the data thereby acquired, no pilot, however daring, lucky or enduring, can hope to remain in the front rank. He must take the guiding hand of meteorology for success and safety. The study of aerology will aid and protect him; it is an applied science.

The International Balloon Race for the Gordon-Bennett trophy was intended to be an annual event, but the war in Europe prevented the race since 1913. In that year, the winner was Mr. R. H. Upson, an American entry, thereby bringing the succeeding race to the United States in 1920. In this contest which was scheduled to start from Birmingham, Ala., October 23, there were seven contestants; one Belgian, one French two Italian and three United States. As usual the race was to start regardless of weather conditions, and was a contest for the greatest straightaway distance from Birmingham to the landing place of the balloon. Landings at sea requiring assistance to land disqualify. The race is not an endurance contest, although it often happens that the old adage, "while you're in the air you're in the race" has a true ring and the longest run is often made by the men longest aloft. In the 1920 race the airmen descended in the vicinity of the Great Lakes (fig. 2), the winner, Lieut. De Muyter of Belgium, landing at North Hero Island, Vt., 1,100 miles from Birmingham.[1]



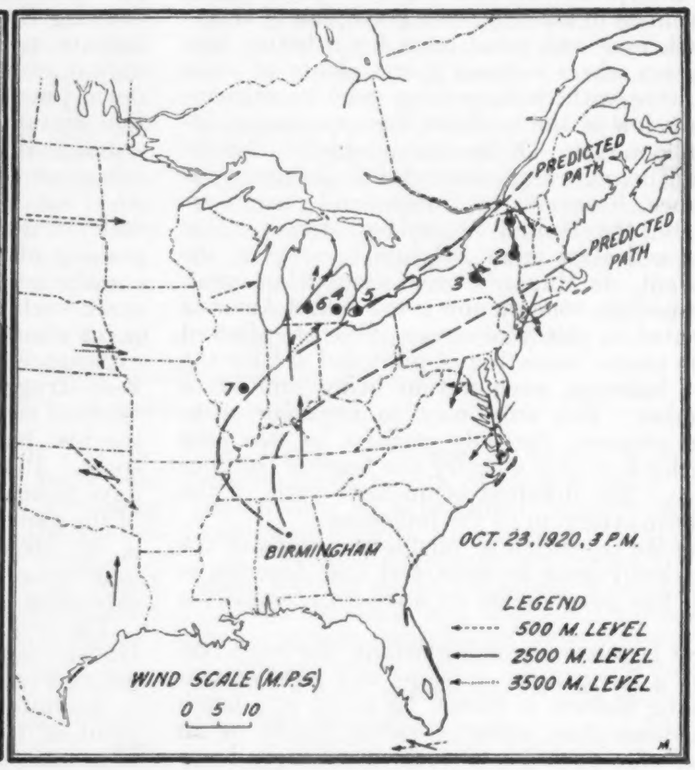


FIG. 1.—Positions of steering and squall-lines.

FIG. 2.—Predicted paths of balloons, actual landing points of balloons (see foot note 1), and upper winds Oct. 23, 1920, at 3 p. m. 75th mer. time.

[1] Numbers beside landing points, in figure 2, indicate the following entries: 1. De Muyter, Belgium; 2. Honeywell, United States; 3. Valle, Italy; 4. Upson, United States; 5. Medori, Italy; 6. Thompson, United States; 7. Hirschauer, France.

It is worthy of note that Lieut. De Muyter is an enthusiastic student of aerology, and for a time was actively engaged in meteorological work in his country. It is notable also that the 1920 event has the distinction of being the first International Race where it was possible to provide a comprehensive survey of weather conditions aloft over the territory to be traversed by the aeronauts. This survey was provided by telegraphic reports of the upper air soundings at pilot-balloon stations of the Weather Bureau, the Army, and the Navy, in the eastern half of the country. This area was thus generally covered by reliable data, but large sections remained where no information could be had, owing to lack of stations equipped for the necessary observations. The need for a closer network of such stations is plain, when it is stated that the Mississippi River flows through the middle of a 400-mile-wide strip of territory from Iowa to the Gulf of Mexico devoid of a station equipped to furnish soundings of the upper air. On this particular occasion the balloons headed for this section when they left Birmingham and voyaged over it during the first 20 hours aloft.

Since this is the first race of a series to be furnished with upper-air as well as surface reports, these reports and the results of the race have been examined with a view to discovering the relationship between the two, and the dependence of the balloonist upon the whims of weather and wind.

Figure 2 shows the landing positions of the several balloons and the predicted path for the successful runs. This prediction was given the pilots and the press at the start of the race; its verification testifies to the reliability and the extent of the Weather Bureau's results in upper-air research. The balloonists took off from Birmingham just before sunset of the 23d, and floated north-northwestward the first night at elevations averaging 1 kilometer. During the following day they made only moderate speed, mostly toward the north, at various elevations. The following night was the crux; at that time those balloonists who had made the least distance westward had entered the freshening winds of the southeast quadrant of a low-pressure area and rapidly spread away from those pilots who had not gained this advantage. The flying during the last 20 hours was for the most part made in clouds and occasionally in rain, these conditions finally requiring the balloonists to descend. The results of the race are conclusive proof that only with the most effective and thorough aerological aid is it possible to win a modern race, even though physical endurance, technically perfect manipulation of the balloon, and a complete equipment may be provided by the pilot. Disregard or misinterpretation of the weather factor meant failure in this race and endurance was a negligible factor, as shown by the fact that the winner was also one of the first to land. Careful and comprehensive use of meteorological material was the factor that won the race.

During the two days the balloonists were flying, a barometric depression of decreasing depth moved from Manitoba northeastward to and beyond Hudson Bay; it carried an ill-defined pressure trough, at first stretching southward from the LOW's center but later lagging at its lower end, hence extending more toward the southwest. A narrow belt of foul weather, mostly of a showery and squally type, clung to the trough and its immediate rear, and cloudy conditions spread ahead over the greater portion of the East. A fine-weather, cool, HIGH remained stationed along the Atlantic coast, but was undergoing a slow disintegration which allowed the invasion of unsettled conditions on its northwestern quadrant during the second day of the race. This distribution of pressure gave assurance of the northward and then eastward drift of the balloons: An assurance that was greeted with great relief by the pilots since it precluded the hazards of a run over the Gulf of Mexico or the southern North Atlantic Ocean. Henceforth the trough of low pressure and the conditions attending it were the chief concerns of the pilots.

Generally, the upper air strata at high altitudes were moving at slow speed from the SW. and at lower altitudes more from the SE., yet of only moderate speed. The strong westerly component which often enters the currents at all elevations during the cold season had not yet appeared at even the highest levels sounded by pilot balloons, this being in close agreement with the precept [2] that the greater the north-south gradient of the surface isotherms the stronger the free-air winds at considerable heights. This condition of small west component persisted throughout the race.

Predicting the life history of a low-pressure trough from surface conditions alone is a very perplexing problem. The most serious failures in forecasting often result from misjudging the character and position of secondary centers of low pressure which often develop in troughs and assume sudden and marked severity. For the meteorologist as well as the balloonist it seems pertinent to make an analysis of the low-pressure trough conditions in the central States during the race. This study has been made in terms of the surface observations of the meteorological elements and the upper-air observations of wind flow, both of which are now regularly available to aeronauts in this country.

The Bjerknes hypothesis[3] of the structure of cyclones and squall lines has much to commend it for use in the present study, since the basic element considered in his solution of the structure of the moving cyclone is the same one which chiefly concerns the balloonist, namely, the wind. This element furnishes two configurations of flow at the surface and lowest levels of the atmosphere under the control of cyclonic formations: One configuration, the steering line, extending outward in front of the circulatory center of the cyclone, the other extending outward on the right-hand side of the center at an angle of from 60° to 120° from the steering line. This is called the squall line. At the surface, both of these lines are located along the convergence of wind streams, with contrasted heat and moisture content and define the surface limits of the warm and cold sides of the storm. Along either of these lines the balloonist finds rough navigating, discontinuous winds and precipitation. The upper-air conditions in the vicinity of these lines are important in their characteristics and in their indications concerning the storm's movement.

The positions of the steering and squall lines of the LOW which passed along the northern border during the race are shown in figures 1 and 3. It will be observed that the flights of the balloons came to a finish near the squall-line position; furthermore, it is clear that the first three were able to make such "easting" during the first leg of the run that they kept ahead of the approaching squall-line as well as availed themselves of the fast-moving SW. to W. winds which are located in the southeast quadrant of all low-pressure areas, at low elevations.

Referring to the upper-air circulation over the general area covered by the balloonists, we find the following

[2] Gregg, W. R.: Note on high free-air wind velocities observed Dec. 16 and 17, 1919 Mo. WEATHER REV., Dec., 1919, 47: 853-854.

[3] Bjerknes, J.: The structure of moving cyclones, *and* Bjerknes, V.: Weather forecasting. Mo. WEATHER REV., Feb., 1919, 47: 90-99.

conditions prevailing on the evening of the 23d: (1) A well-defined circular wind system central over Pennsylvania and constant up to the 4-kilometer altitude, representative of the free-air circulation in a well-marked HIGH, especially of the type whose control of surface conditions wipes out the temperature gradients between the north and the south; (2) the absence of the typical squall-line characteristics of shelving and counterflow of the converging windstreams; (3) the low velocities above the 3-kilometer level, indicative of slight and varying west component in the wind flow at those levels; and the presence above the 2,500-meter level of a south component. During the next two days the anticyclonic whirl over the Atlantic coast moved off to sea, while in the upper air over the sector marked out between the steering and squall lines of the LOW the winds were typical of that location, composed of moderate to fresh velocities from the SW. or WSW. as far west as the situation of the forerunner of the squall line; in this case about 100 miles to the front of the surface squall line.

The nonexistence of a strong west component in the upper air was a disadvantage to the balloonists, inasmuch as it furnished no relief from the fickle winds of the lower altitudes just ahead of the squall line. One balloonist rose to a height of 6 kilometers seeking the oft-mentioned "prevailing westerlies" of the upper air. Incidentally, he was in the midst of a snowstorm from the 3-kilometer up to the 6-kilometer level—an indication of the location of the squall line aloft, since this occurred in eastern Michigan near noon of the 25th and considerably in the rear of the surface squall line at that time. It confirms the belief that the squall front reaches the ground layers first and the upper layers progressively later, along the upper side of the flat wedge of cold air.

The best distances should be found to have been made by those pilots who were able to stay the longest time in the outer currents of the HIGH during the first part of the race, and who were then able to pass from this anticyclonic control into the best winds of the cyclonic, viz, the WSW. winds of that part of the LOW's warm sector where those winds would be available the longest possible time before they would draw the airmen into the precipitation area or squall line of the LOW. This was the course followed by the winners. The others found themselves drawn onto the squall line far to the rear of the cyclone and, once within the control of this line, they were forced down by precipitation or the need of escaping the possibly violent turnover of the winds at that line. The squall line retains its reputation as a wave of air practically impossible to navigate at any level of the atmosphere within reach of the free-balloonist.

It may rightly be inquired whether it was possible to predict the conditions encountered and what was the best procedure in selecting the most favorable level to maintain at various stages of the run. The forecasts and advisory statements were verified closely, the best distances being made along the routes indicated by the forecasts, and conditions there agreed with those predicted. It was also possible to indicate to the pilots what many likely conditions would mean if encountered. It should be remembered that free-ballooning requires forecasts, which, unlike the usual weather forecasts, are designed to cover a moving area for the long period of at least 48 hours, in a specific statement devoid of mere probabilities or reservations. Forecasting for free-balloon runs is peculiarly exacting, since the balloonist must drift with and not across the wind to a possible position more favorable. The entire prediction is therefore a series of forecasts successively dependent upon the successful fulfillment of each one previous. Such forecasts may have occasional alternative statements definitely covering two distinct weather processes either of which will be distinguishable for the pilot upon his flight. It must be taken into account that the pilot is unable to escape the warming and consequent expansion and increased lift of his gas bag in sunshine, and the cooling and consequent contraction and decreased lift in the shade. Air temperature and precipitation are also important considerations, since they, too, affect the weight and buoyancy of the balloon. What is true of the value of forecasts to free-balloons is largely true of their value to propelled airships, and likewise to airplanes. Free-balloon forecasts should cover the wind drifts at each flying level, the cloudiness, the sunshine, the precipitation (both amount and type of generation), the electrical activity, and the temperature.

It was impressed on the pilots in the present race by written forecasts and verbal consultation that the best procedure was to get as far north and east as possible the first 24 hours. Westward motion was advised against, and climbing advocated, if necessary, to keep away from the converging winds of the squall line, and to bring the balloons into the W. or SW. winds on the southeast side of the LOW on the second night of the race. The calm region near the forerunner of the squall line was described as a warning of the turnover squall to follow, and it was stated that the only possible relief, and then but a doubtful one, was to rise and endeavor to find a somewhat stronger westerly current at a higher level. It was advised, in the face of the usual practice and the generally sound policy of balloon pilots, that an expenditure of considerable ballast the first night would be true economy, since the upper winds at that time were directed more to the east than the lower, consequently peculiarly adapted to this race.

It is a natural conclusion that effective assistance can be rendered by an efficient consulting meteorologist to any aerial event of importance. He should be called upon not only to select the favorable flying levels in the next few hours, but also to analyse and describe the meteorological series of events which the flyer will encounter. He should also indicate to the flyer what changes will be likely in the structure of the atmosphere, and what will be the effect of deviation of the actual events encountered from those forecast, with special attention to the signs of approaching bad weather, applicable in the case. The forecasts should be intended to advise concerning the best flying procedure rather than merely warn concerning the worst.

The attitude of aeronauts toward guidance by a trained aerologist is not always one of amenability. Aviators, in balloons and in planes, are often of a type characteristically daring and aggressive; they enjoy to a degree the obstacles presented by difficult weather. Some airmen instinctively feel that meteorological advice deprives flying of some of its sporting chances and of its gameness, and consistently will not avail themselves of the assistance of the aerologist. But the really big aerial programs, transoceanic flights, and long-distance contests are carried out under the direction of capable advisers in aerology, and the time will shortly arrive when flights without aerological assistance will be relegated to the dubious sphere of stunt flying. The more efficiency is aimed at, in the operation of aerial transport, the more exacting will be the demand for upper air reports and predictions.

THE APPLICATION OF BJERKNES LINES TO THE DEVELOPMENT OF SECONDARY LOWS.

By C. G. ANDRUS, Observer.

[Weather Bureau, Due West, S. C., Feb. 25, 1921.]

SYNOPSIS.

The application of the Bjerknes lines of wind convergence to the solution of the problems of trough development at the time of the National and International Balloon Races in September and October, 1920, afforded some useful conclusions concerning the principles of the Bjerknes hypothesis in secondary LOWS. This study has been made purposely only in terms of the surface elements and the winds aloft. Irregularities in these conditions, can be traced to imminent development of a change in the cyclonic formation. A description of these irregularities both at the surface and aloft has been made in order to record some forecasting hints, which, while neither infallible nor complete, offer some aid in detecting the sudden development of secondary LOWS in barometric troughs.

It has been mentioned [1] that the barometric trough requires cautious treatment by the aeronautical forecaster. The problem presented by these troughs does not concern merely the trough, for its effects on weather elements are well understood; the real problem is this: Will a secondary unit of low pressure develop in the trough, and if so, where and when will this occur? This was the major meteorological problem met in the preparation of advisory forecasts for the flyers in the National Balloon Race from Birmingham, Ala., September 25, 1920, and at that time the converging wind streams which have been discussed by Bjerknes were found extremely helpful. The results were so satisfactory that at the time of the International Race a month later considerable reliance was placed on this method for a solution of the problems of a somewhat similar pressure distribution. The conclusions reached by the study of these two troughs, and of many others previously examined, are based almost entirely on wind flow and temperature data, as it has seemed evident that the sea-level barometric values [2] are of doubtful meaning in defining the position or motion of the center of activity in these depressions. However, the Bjerknes system considers the cyclone which is moving and definite, so it has been necessary to adapt it to use on the indefinite depression.

So long as a squall line exhibits only the well-known properties of the line squall in more or less intense degree it may be treated as the normal squall line of Bjerknes. But should the squall line or the conditions along its extension manifest any tendency to resemble the properties of the steering line, this condition is likely to herald the birth of a separate cyclonic unit, and keen watch must be kept of this action. If the condition persists, it indicates a secondary LOW in process of formation; if it appears to be but temporary, it is nevertheless an excellent marker of the position on the squall line of possible future developments. In the steering line we have the elements of the inclined plane, its lower edge coinciding with the surface position of the steering line, its face containing the steering line's positions at successive levels aloft, and extending upward to the north of the line of travel of the depression. In the case of the steering line the inclined plane exerts no wedging force, but is propelled forward along the line of the storm's movement in a sideling fashion. Warm winds usually of southerly component, glide up the surface of the plane, which is composed of relatively cooler winds directed inward toward the storm center at an angle of considerable incidence to the isobars. The steering line, therefore, may be considered as a surface condition of passive character where wind streams leave the surface in a gradual ascent whose position is marked by cloud bases and usually announced by continuous rain or snow, and sometimes sleet.[3]

The squall line, on the other hand, is an inclined plane wedging forward in the same general direction as the LOW. This wedge, whose flat side in on the surface, consists of air relatively colder and heavier than the air it displaces, which is pried upward and forward. The line squall and the "clearing" shower are manifestations of the squall line passage. In the case of the squall line, the surface condition is one of increasing activity, this being first displayed there, and later and more to the rear, shown aloft. If topography is disregarded, the strongest winds of the surface circulation in a definite LOW are those at and immediately to the rear of the squall line, and those in the front half of the warm sector between the steering and the squall lines. Conversely the weakest or most variable winds at the surface occur just ahead of the steering line and over the forerunner of the squall line. This latter location is sometimes clearly marked by a widening of the isobars of the weather map and is occasionally the birthplace of tornadoes.

When a steering line exhibits characteristics of a squall line, the depression will weaken in intensity and lose definition. In this class are those steering lines whose east and north winds are too strong, have too strong a north component, or are irregularily deflected across the isobars.

The squall line is usually much better defined and of much greater extent, so that a departure from its normal form can be more promptly detected. When a squall line shows any characteristics of a steering line, the propagation of a secondary unit of cyclonic circulation may be expected at the location of the irregularity, if it persists more than 12 hours. These irregularities are manifested as, (1) the entering of an east or the falling off of the proper west component directly at the rear of the squall line; (2) the development of precipitation of a steady rather than shower type to the front of the squall line, an indication of the upriding southerly currents rather than the underrunning northwesterly or of the occurrence of both of these actions; (3) the failure of the line of falling temperature to proceed forward along a solid front but instead, making an enveloping attack on the warm area; (4) the lagging of the lower end of the squall line, resulting in the orientation of this end toward the southwest and west in greater degree, hence giving greater opportunity for irregularities (1) and (3) to become operative. The steering line of a developing unit of cyclonic circulation may be expected to occur along the location of these four irregularities, all four of which are sometimes present.

Conditions aloft are more indeterminable in the present scattered condition of the available observations. Sometimes only two points are available over an immense area, and two points will not determine a plane. But we may judge where a squall line's plane should cut successively higher layers of the atmosphere and determine

[1] Andrus, C. G.: Meteorological aspects of the International Balloon Race, 1920. This REVIEW, pp. 8-10.

[2] Meisinger, C. LeRoy: Preliminary steps in the making of free-air pressure and wind charts. MO. WEATHER REV., May, 1920, 48: 251-263.

[3] Meisinger, C. LeRoy: The precipitation of sleet and the formation of glaze in the eastern United States, Jan. 20 to 25, 1920, with remarks on forecasting. MO. WEATHER REV., Feb., 1920, 48: 73-80.

whether the actual wind approximates the estimated wind for that position, laying great stress on the actual wind's direction. Hence we may consider as irregularities aloft, (1) in the rear of a squall line, any SE., E., or light NE. wind above the 1,500-meter altitude (there the wind should be westerly and equal to or stronger than the 500-meter altitude wind), (2) to the north of the steering line, the lack of a marked veering of the higher altitude winds with reference to those at lower levels, (3) too strict an adherence of the wind motion at an elevation of about 600 meters above ground to the gradient values deduced from isobars for the sea level along the region in the vicinity of the steering and squall lines. The 600-meter wind along the squall line should be extraordinarily deflected outward across the isobars, and the 600-meter wind along the steering line should be somewhat deflected inward across the isobars.

The formation and propagation of a secondary in the lower end of the trough of low pressure in the central States during the International Balloon Race was foretold by irregularities in the wind streams. The first appeared over central Texas on the evening of October 23d, when rain was reported well in front of the squall line in Texas. The upper winds at 2,500 and 3,500 meters altitude (fig. 4) in the rear of the squall line over Oklahoma showed a pronounced easterly and southerly component, indicative of the overrunning of the cold current by one from the south. Absence of marked west winds at altitudes up to 4 kilometers over the Southwest and Middle West was an indication of the slow movement of the cyclonic unit after its formation. The following day at 8 a. m., a definite subcenter of low pressure had become established in eastern Texas and the steady rain area had extended over eastern Texas, western Louisiana, Arkansas, and Missouri; a line of convergent wind streams, which we may consider a steering line, extended northeastward from northeast Texas; another convergence line, the squall line of the new circulation center, extended from northeast Texas southeastward to the Gulf coast. The secondary LOW was now a definite one, yet the large size of its warm area without marked increase of temperature on its front, and the position of the HIGH to the northeast meant that the countercurrents were not dynamically powerful enough to feed an intense storm, hence the development of the depression was but moderate. The wind at the altitude of 3 kilometers and 4 kilometers had apparently increased in westerly component throughout the Middle West, since the only two available observations, at Madison, Wis., and Kelly Field, Tex., found WSW. winds of 17m/s. and 10 m/s., respectively, at the 4 kilometer level that morning. From this is was concluded that the forward movement of the storm would be slower than normal at first, but later increasing somewhat as it reached higher latitudes.

To summarize, it may be stated that of the available observations the most effective in predicting the formation of secondaries are the wind convergence lines, at the surface and aloft, the temperature contrasts, the barometric gradient, and the deflection of the actual wind along the isobars. The 600-meter altitude has been found to represent the approximate position of the gradient wind above ground, although this altitude is sometimes taken as low as 300 meters. Prevention of the failures of forecasts due to suddently forming Texas or Gulf LOWS may be increased by the application of the principles just considered. Other principles of wind-shifts and free-air motions have been found, but have been observed too seldom to warrant their consideration until further material is obtained.

ORIGIN OF SOME SECONDARY CYCLONES ON THE MIDDLE ATLANTIC COAST.

By CHARLES F. BROOKS, Meteorologist.

[Weather Bureau, Washington, D. C., Mar. 1, 1921.]

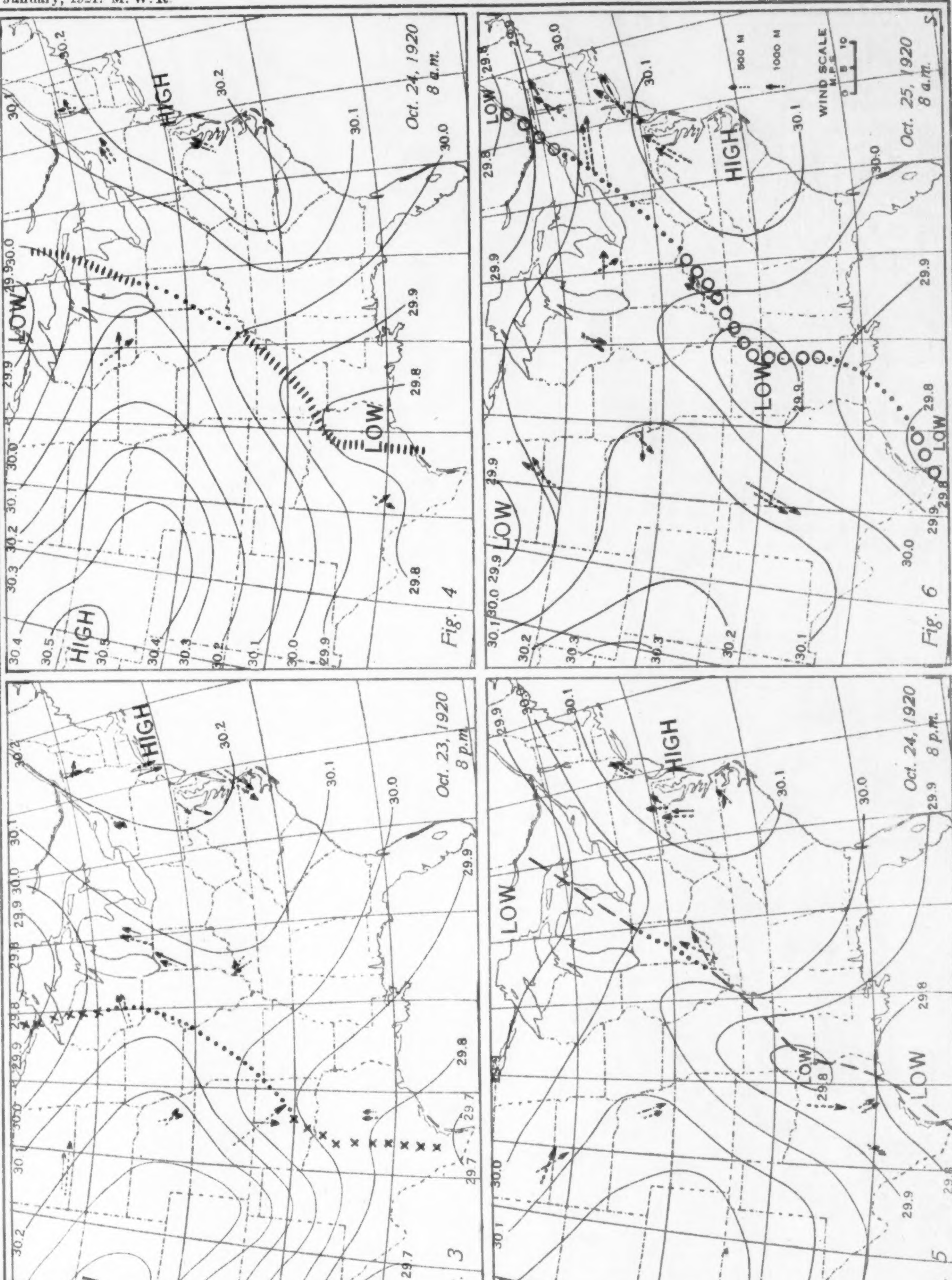
SYNOPSIS.

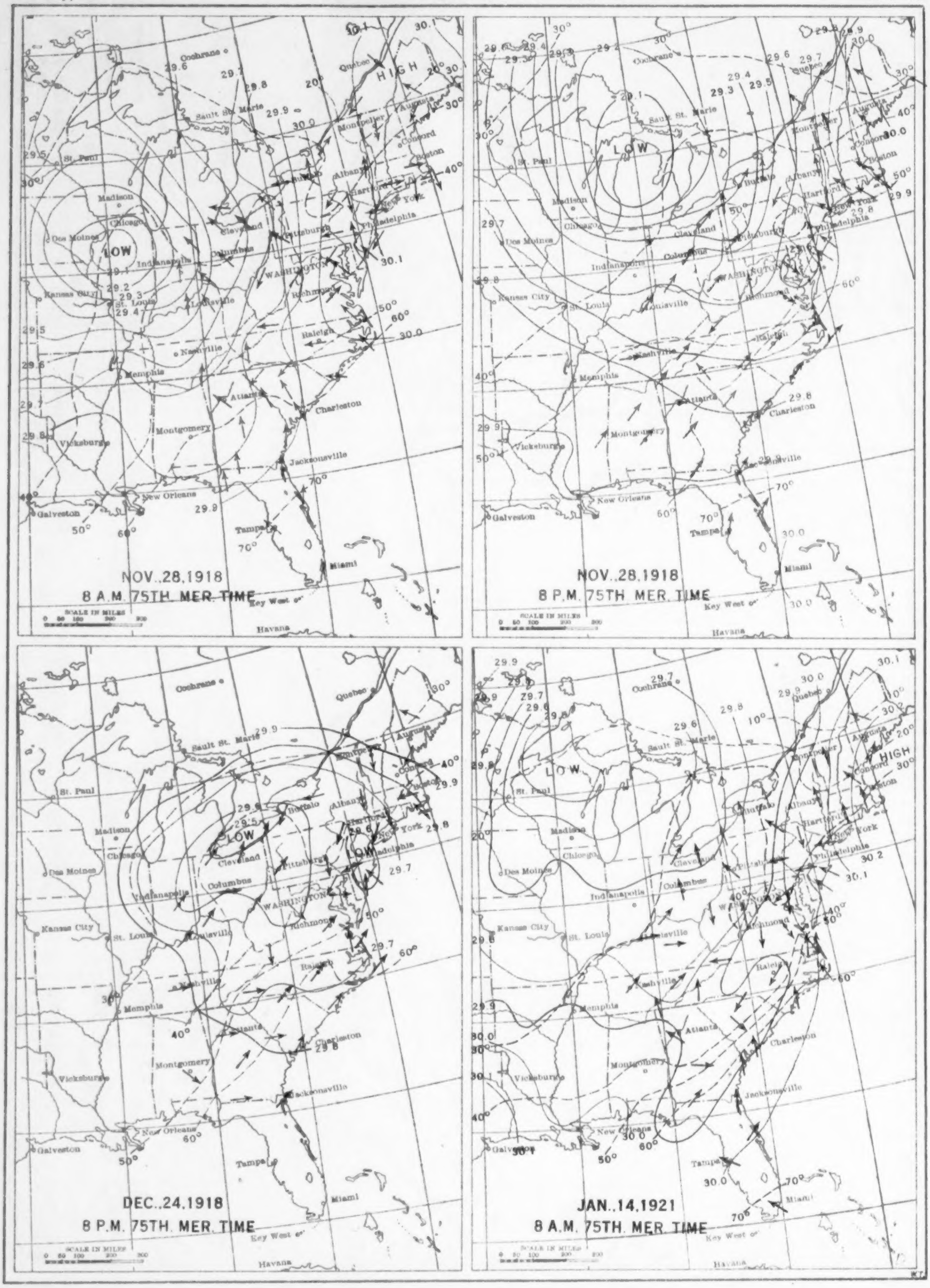
When a strong cyclone centered in the Middle West extends its influence to the Atlantic coast a small secondary low-pressure area is often formed just inland from the coast. The southerly wind readily establishes itself at the surface along the low, flat coast, and therefore brings about a rapid fall in pressure not only by blowing away the dense, cold air, but also by bringing much warmer air soon from over the Gulf Stream. Perhaps a hundred miles inland, on the other hand, the relative roughness of the land tends to retain the cold surface air for some time, while the southerly wind rides over it. Once the pressure along the coast has become lower than that inland, a secondary cyclone develops and survives for the short time till the relatively small volume of cold air becomes mixed with the warm and blown away.

With the approach of a large cyclone from the Middle West, the cold air of the preceding anticyclone is more rapidly swept away by the southerly wind along the flat coast than over the maturely dissected Piedmont backed by such an effective retaining wall as the Blue Ridge. Furthermore, the arrival of warm air from over the Gulf Stream occurs much sooner on the coast than 100 miles inland at the same latitude. For example, a SSE. wind would have to travel 200 miles from the Gulf Stream to reach Norfolk, Va., and 300 miles to reach Lynchburg. With the substitution of the more tenuous, warm air for the denser cold air taking place from sea-level to an appreciable height, the atmospheric pressure on the coast falls rapidly. Inland, however, the substitution of more tenuous for denser air is in progress only above the retained, surface layer of cold air, which may extend, near the mountains, up to 500 or more meters above sea level. Thus, even were there no change in relative pressure at, say, 1,000 meters above sea level, a closed area or trough of low-pressure would form over the coast, or rather just inland, because the lowest pressure would occur just west of the place of greatest fall, the pressure gradient originally having been from east to west. In accordance with the new distribution of pressure the cold air hugging the Piedmont starts to move southwestward and southward. This movement brings colder air in greater volume, which tends to raise the pressure over the Piedmont at the same time that the warmer and warmer air arriving over the coast is lowering the pressure there. Thus, the secondary low-pressure area becomes strengthened, and its cyclonic circulation becomes complete—all within the lowest kilometer or two of the atmosphere. Through holes in the lower clouds, the heavy St.Cu. and A.St. at about 1.5 or 2 kilometers may be seen moving rapidly from the SW. over the whole area, in conformity with the more or less regular distribution of pressure about the primary cyclone hundreds of miles to the northwest. The cold air over the Piedmont provides a steep mountain slope up which the warm air from the Gulf Stream rises, expanding and discharging much of its great load of moisture.

Before long, the east winds in the northeast quadrant of the secondary have pushed in from the ocean to the Blue Ridge. The supply of cold air is becoming adulter-

C. G. A. I.—Weather Conditions During International Balloon Race, October 23-25, 1920.




NOV. 28, 1918
8 A.M. 75TH MER. TIME
NOV. 28, 1918
8 P.M. 75TH MER. TIME
DEC. 24, 1918
8 P.M. 75TH. MER. TIME
JAN. 14, 1921
8 A.M. 75TH. MER. TIME
SCALE IN MILES

ated with warmer air. The oceanic wind turns and goes southwestward along the Piedmont. Aloft, the increasing southerly wind of the primary cyclone is slowly, but surely, wearing down the cold mass of air over the Piedmont. A stage is reached when the attacks from the northeast and from the southwest finally break through to the ground; and the remaining layer of cold air, turbulently mixed with the warmer air, goes north. The backbone of the secondary cyclone is thus removed. The fog blows away and skies clear.

The pressure over the Piedmont having fallen rapidly, in consequence of the replacement of the cold air by much warmer air now from far south, the seaward pressure gradient of the secondary is weakened and destroyed. The primary LOW speeds forward where previously it had been delayed on approaching the band of cold air. A cyclone has been born, lived a day and died.

The foregoing description fits closely the conditions on Thanksgiving Day (Nov. 28), 1918 (see figs. 1 and 2). Partial developments are common in the colder half-year. On October 29, 1917, a weak secondary cyclone developed and lasted till nearly midnight, when the cold air was blown away violently and a tornado formed.[1]

Two other examples may be cited. On the morning of December 24, 1918, there was an intense cyclone centered in Illinois. The winds on the middle Atlantic coast were still northeasterly from a northeastern HIGH. By noon the wind at Manteo, on the coast of North Carolina, had become south, and by night the south wind had established itself on the coast north to Atlantic City, N. J., and a secondary had developed (see fig. 3.) The next morning, the primary center was over northern New York, and there was still a weak remnant of the secondary centered apparently in southeastern Connecticut. The rainfall was heavier about the secondary than close to the center of the primary cyclone. Part, if not all, of the excess, however, may have been the natural result of rainfall which usually accompanies warm on-shore winds in winter. A trough-like secondary developed overnight and was apparent on the weather map for 8 a. m., January 14, 1921 (see fig. 4). The contrast in temperature between the cold air inland and the warm wind on the coast was particularly great; at Norfolk, Va., there was a SE. wind of 30 miles an hour, with a temperature of 56° F., while at Richmond, 40 miles away, the wind was NW. at 6 miles an hour, with a temperature of 32°. The rain falling from the warm overriding wind froze into glaze over considerable areas in central and northern Virginia and northeastward. No rain fell where the surface wind was south, but where the strong wind rode up over the wedge of cold air heavy rains, locally more than 1 inch, fell.

I am indebted to Mr. C. LeRoy Meisinger for making the portions of the synoptic charts reproduced as figures 1 to 4.

[1] See Mo. WEATHER REV., Oct., 1918, 46:460-464. Weather maps for the evening of Oct. 29 and the morning of the 30th are produced on p. 462, and diagrams showing ocal weather changes, on p. 463.

NOTE ON DEEP EASTERLY WINDS OVER THE MIDDLE WEST ON JANUARY 24, 25, AND 26, 1921.

By LEROY T. SAMUELS, Observer.

[Weather Bureau, Washington, D. C., Feb. 19, 1921.]

SYNOPSIS.

Kite flights and pilot balloon observations made in the north-central portion of the United States on January 24, 25, and 26, 1921, showed easterly winds persisting to heights of 3 kilometers or more. Easterly winds at these altitudes are rare in the United States during the winter season on account of the strong latitudinal temperature gradients usually existing. Pressure was generally high to the north of this region and low in the south, with a moderately steep surface temperature gradient extending from south to north. A large temperature inversion at Ellendale, however, caused the pressure to remain higher over this region, at least to 3 kilometers, than at Drexel where isothermal conditions obtained to 2,500 meters elevation.

On January 24, 25, and 26, 1921, upper-air soundings made in the north-central portion of the United States by means of kites and pilot balloons showed easterly winds extending from the surface to unusual heights. As is well known, easterly winds of considerable depth are rare in this country during the winter season, on account of the steep latitudinal temperature gradients usually existing. When such winds *are* found, they indicate that abnormal causative conditions prevail and it is well worth while to inquire, in some detail, what those conditions are.

During the period under consideration pressure was generally high north of the Canadian border, and low over the central and southern portions of the United States. On the morning of the 24th a HIGH (30.7 inches) was central over Manitoba, and a LOW (29.75 inches) over western Kansas. Accompanying this pressure distribution was a moderately steep surface-temperature gradient extending from south to north with 0° C. at Omaha and −24.4° C. at Winnipeg. By the 26th the HIGH (30.7 inches) was central over Ontario and the LOW (30.05 inches) over southern Alabama, still showing a strong surface-temperature gradient ranging from −6.7° C. at Indianapolis to −28.9° C. at Stonecliffe, Ontario.

As a rule, under conditions like those just described there is found at a short distance above the surface a complete reversal in the pressure distribution, because the cold, and therefore denser, air in the north causes a diminution of pressure in the higher levels and the warmer air in the south tends to increase the pressure aloft, thus causing a reversal of the wind direction found at the surface.[1]

As already stated, however, no such wind reversal was found, but instead an easterly component persisted to altitudes of 4 to 5 kilometers. The extent and duration of the easterly winds are shown in Table 1. The observations may be briefly summarized as follows:

[1] Gregg, W. R.: Note on high free-air wind velocities observed Dec. 16-17, 1919. Mo. WEATHER REV., Dec., 1919; 47: 853-854.

TABLE 1.—*Free-air winds observed in the north-central part of the United States on Jan. 24, 25, 26, and 27, 1921.*

Stations.	January—	Time (local standard).	Altitude (meters) above sea-level. Surface.		500		1,000		1,500		2,000		2,500		3,000	
			Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).
Ellendale, N. Dak.	24	8:45 a. m.	ene.	3	e.	5	e.	13	e.	10	ene.	5	ne.	8	ene.	3
	24	3:20 p. m.	ne.	9	ne.	8	e.	11	ese.	13	e.	10	e.	9	e.	8
	25	9:00 a. m.	nne.	4	nne.	3	se.	4	se.	6	se.	8	e.	6	ene.	8
	25	2:20 p. m.	sse.	2	sse.	2	se.	4	s.	2	w.	3	ene.	1	ene.	2
	26	8:35 a. m.	sse.	7	sse.	8	ssw.	6	sw.	6	ssw.	7	sw.	10	sw.	9
	[1] 24	8:33 a. m.	ne.	5	ne.	7	ene.	13	ene.	10	ene.	7	e.	6	ese.	6
	[1] 24	12:54 p. m.	ene.	9	ene.	9	ene.	13	ene.	14	ene.	11	ene.	8	ene.	7
	[1] 24	4:48 p. m.	ne.	8	ne.	9	ene.	14	e.	13	e.	11	ese.	10	ese.	12
	[1] 24	8:41 p. m.	nne.	6	nne.	7	e.	12	e.	11	ese.	11	ese.	10	ese.	11
	[1] 25	1:27 a. m.	nne.	4	ne.	5	e.	11	e.	10	e.	11	e.	8	e.	6
Drexel, Nebr.	[1] 24	8:14 a. m.	e.	12	e.	13	e.	18	ese.	16	ese.	13	se.	12	se.	12
	[1] 25	12:45 p. m.	ne.	6	ne.	8	ne.	9	nne.	7	nne.	6				
Fort Omaha, Nebr.	24	8:24 a. m.	e.	6	e.	8	ese.	17	ese.	14	ese.	14	se.	9	se.	11
Madison, Wis.	24	2:49 p. m.	ne.	8	ne.	6	ene.	6	ne.	7	nnw.	6				
	25	7:17 a. m.	ne.	6	ene.	7										
	25	2:57 p. m.	e.	6	e.	10	e.	10								
	26	7:18 a. m.	ene.	4	e.	4	e.	4								
Royal Center, Ind.	25	7:08 a. m.	e.	11	e.	10	e.	9	e.	8						
	25	1:59 p. m.	ene.	12	e.	12	ese.	13	ese.	10	ese.	7	se.	6	sw.	6
	26	7:16 a. m.	ne.	8	ene.	11	e.	13	e.	12	e.	12	e.	11		
	26	2:03 p. m.	ne.	5	ene.	4	ene.	6	e.	7	ene.	5	e.	7	ene.	6
	27	7:02 a. m.	se.	[2] 0	ne.	2	n.	3	w.	3	w.	5	w.	5	wnw.	6
	[1] 26	8:16 a. m.	ene.	8	ene.	11	e.	11	e.	11	e.	10	e.	10	e.	11
	[1] 26	11:45 a. m.	ne.	6	ne.	7	ene.	7	e.	8	e.	7	e.	7		
	[1] 26	3:45 p. m.	ne.	4	ne.	4	nne.	2	ene.	2						
	[1] 26	7:43 p. m.	nne.	3	ne.	4	e.	2								
Lansing, Mich.	25	7:00 a. m.	ene.	4	e.	7										
	25	2:57 p. m.	ene.	3	ene.	6	e.	7	e.	9	ne.	8	nne.	6	nnw.	6
	26	6:55 a. m.	e.	3	ene.	5										
	26	3:02 p. m.	ne.	1	n.	2	e.	2	e.	[2] 0	n.	1	w.	3	w.	4

Stations.	January—	Time (local standard).	Altitude (meters) above sea-level. 3,500		4,000		4,500		5,000		6,000		7,000		8,000	
			Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).
Ellendale, N. Dak.	24	8:45 a. m.	e.	2	sse.	1										
	24	3:20 p. m.	ese.	6												
	25	9:00 a. m.	ene.	6	ene.	5										
	25	2:20 p. m.	n.	3	nnw.	4	nnw.	4	nnw.	6						
	26	8:35 a. m.	sw.	9												
	[1] 24	8:33 a. m.	se.	5												
	[1] 24	12:45 p. m.														
	[1] 24	4:48 p. m.	se.	8												
	[1] 24	8:41 p. m.	se.	13												
	[1] 25	1:27 a. m.														
Drexel, Nebr.	[1] 24	8:14 a. m.														
	[1] 25	12:45 p. m.														
Fort Omaha, Nebr.	24	8:24 a. m.														
Madison, Wis.	24	2:49 p. m.														
	25	7:17 a. m.														
	25	2:57 p. m.														
	26	7:18 a. m.														
Royal Center, Ind.	25	7:08 a. m.														
	25	1:59 p. m.	sw.	9												
	26	7:16 a. m.														
	26	2:03 p. m.	ne.	7	ene.	7	ne.	8	nne.	8						
	27	7:02 a. m.	nw.	8												
	[1] 26	8:16 a. m.														
	[1] 26	11:45 a. m.														
	[1] 26	3:45 p. m.														
	[1] 26	7:43 p. m.														
Lansing, Mich.	25	7:00 a. m.														
	25	2:57 p. m.														
	26	6:55 a. m.														
	26	3:02 p. m.	wnw.	4	wnw.	6	wnw.	6	wsw.	6	wnw.	7	nnw.	13	nw.	26

[1] Observations from kite flights; all others from pilot balloon ascents; altitudes in the latter are determined from an assumed constant rate of ascent.
[2] Less than 0.5 m. p. s.

NOTE.—The altitudes of the stations above sea-level are: Ellendale, 444 meters; Drexel, 396 meters; Fort Omaha, 350 meters; Madison, 307 meters; Royal Center, 225 meters. Lansing, 263 meters.

Five kite flights were made at Ellendale, N. Dak., from 8:33 a. m., January 24 to 5:05 a. m., January 25. It was impossible to continue the series, as a sixth flight reached an altitude of only 350 meters above the surface, due to diminishing wind velocities. In all of these flights easterly winds prevailed to the highest altitudes reached. Pilot balloon ascensions at Ellendale on the 24th, likewise indicated easterly winds with decreasing velocities in the higher levels up to 3,600 meters and 3,400 meters for the a. m. and p. m. observations, respectively. In both cases the balloons burst before they had reached the A.St. cloud layer which was observed to be moving from the SW. On the morning of the next day, however, clouds were observed here as follows: 6/10 Ci.St., E., 1/10 A.St., E., and 2/10 A.Cu., E. The balloon during this run burst at the 3,500-meter level and indicated easterly winds to this height.

Four kite flights were made at Royal Center, Ind., from 8:16 a. m. to 9:30 p. m., January 26, and easterly winds were found at all altitudes reached. On the morning of the same day A.St. clouds were observed moving from the east but unfortunately the pilot balloon was obscured by the instrument tower when the 2,500-meter level was reached. The afternoon balloon run indicated an easterly wind to 4,000 meters shifting to north-northeast at 4,800 meters when the balloon was observed to burst.

At Lansing, Mich., the easterly winds were not of such great depth as at Ellendale and Royal Center. The afternoon balloon run of the 26th indicated northeast to southeast winds from the surface to 1,500 meters, then shifting through north to west and northwest to 8,000 meters, at which altitude the balloon was lost to view.

The cause of these easterly winds at high altitudes is made apparent by an examination of the free-air temperatures observed at Drexel and Ellendale. Figure 1 shows that on the morning of the 24th there was a large temperature difference at the surface, but that up to 2,500 meters practically isothermal conditions prevailed at Drexel, whereas there was a large inversion at Ellendale, the result being that in the upper levels the horizontal temperature gradient between the two stations was comparatively slight. The effect of this temperature distribution on the free-air pressures is shown in Table 2.

TABLE 2.—*Free-air pressures at Ellendale, N. Dak., and Drexel, Nebr., on the morning of Jan. 24, 1921.*

Station.	Altitude (meters) above sea level—							
	500	750	1,000	1,250	1,500	2,000	2,500	3,000
	mb.	*mb.*	*mb.*	*mb.*	*mb.*	*mb.*	*mb.*	*mb.*
Ellendale..........	970.7	939.8	909.6	880.3	852.6	800.5	751.6	704.7
Drexel..............	962.6	932.8	904.2	876.7	850.0	798.5	750.0	704.3

It will be noted that the pressures at Ellendale remain higher than those at Drexel up to 3 kilometers. It is apparent, though, that a reversal occurred at a slightly greater altitude than this—a condition favorable for westerly winds, and this is in agreement with the observed northeastward movement of the A.St. clouds.

By the morning of the 25th the easterly winds extended to a still greater height, as shown by the pilot balloon and upper-cloud observations made at that time. Comparison of free-air temperatures in this case is not possible, owing to the relatively low altitude reached at Drexel, but it is to be noted that the daily weather map shows on this day a weaker latitudinal temperature gradient than on the preceding day, and it is to be presumed that a correspondingly weak gradient prevailed in the upper levels. The same statement and deduction may be made with respect to the easterly wind that extended at least to 5 kilometers on the afternoon of the 26th at Royal Center. An isothermal condition existed during all four kite flights at Royal Center but because there

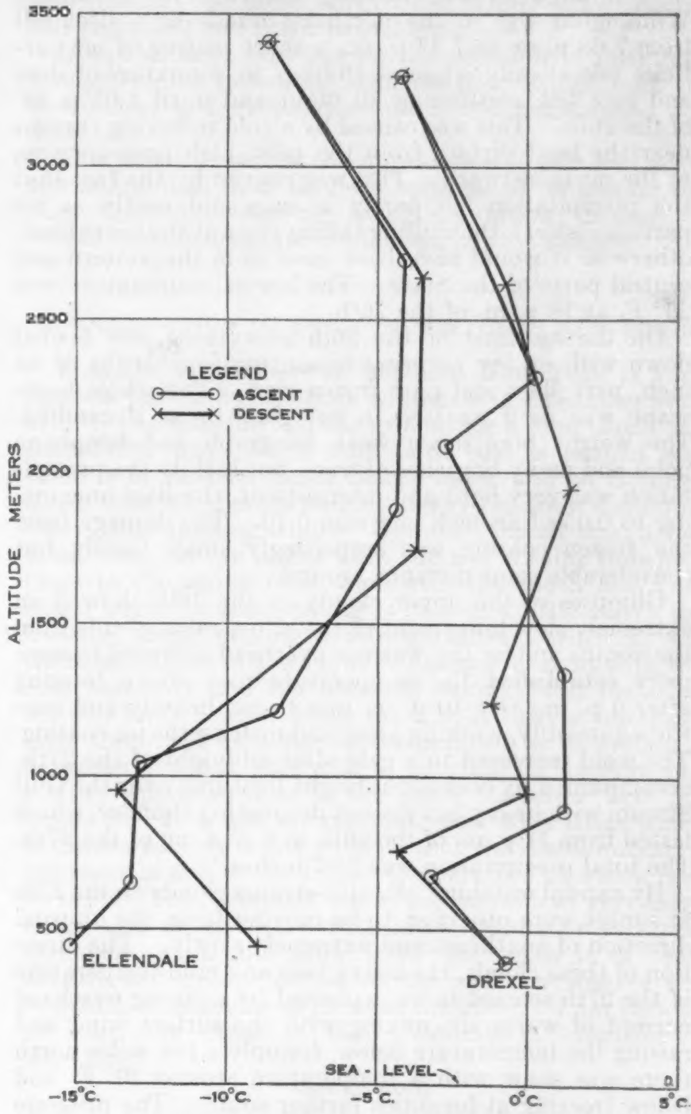


FIG 1.—Simultaneous free-air temperatures, °C., at Ellendale, N. Dak., and Drexel, Nebr., on the morning of Jan. 24, 1921.

are no kite stations within a reasonable distance to the south, actual comparisons can not be made.

ICE STORM AND GALE OF JANUARY 25-27 AT WILMINGTON, N. C.

By R. M. DOLE, Observer.

[Weather Bureau, Wilmington, N. C., Jan. 30, 1921.]

The morning map of January 25 showed an oval depression in eastern Kansas which had moved to Mississippi by night and become a round and weak LOW surrounded by abnormally high pressure. The isobars were rather far apart, but the range in pressure and temperature to the northeastward was large, pressure being over 30.6

inches over the Lakes. Temperature in New England was near zero, while it was above 60° F. along the Gulf coast.

The alto-stratus clouds moving from the west the night of the 25th were typical, showing the presence of warm currents aloft running ahead of the LOW. The shape of the depression and its enveloping high pressure were indicative of heavy snow in the northwest quadrant and sleet through its axis running southwest to northeast. Wilmington was in the northeast quadrant. Sleet fell from 7:08 p. m. to 7:14 p. m., a short pelting of ice particles (sleet) only, while at 10:05 p. m. a mixture of sleet and rain fell, continuing all night and until 1:05 p. m. of the 26th. This was caused by a cold inflowing current near the land surface from the cold, high pressure area to the northeastward. This was proved by the fact that the precipitation fell partly as rain and partly as ice particles (sleet), the chilling taking place at the lower level, otherwise it would have been snow as in the western and central parts of the State. The lowest temperature was 26° F. at 10 a. m. of the 26th.

On the morning of the 26th everything was loaded down with an icy covering measuring four-tenths of an inch, part sleet and part frozen rain. The whole landscape was as if encased in cut glass or as if candied. The weight bore down weak telegraph and telephone poles and many branches of trees, but luckily the precipitation was very light and intermittent, the sleet amounting to 0.05 of an inch and rain 0.10. The damage from the frozen coating was surprisingly small locally but considerable some distance around.

Glimpses of the upper clouds on the 26th showed an extremely slow movement of the alto-stratus clouds from the south, and as the warmer overhead currents became more established the temperature rose above freezing after 6 p. m. By 10 p. m. rain began heavily and continued steadily, washing away and melting the ice coating. The wind increased to a gale after midnight of the 27th, accompanied by occasional bright lightning over the Gulf Stream with heavy but distant detonating thunder, which lasted from 11 p. m. of the 26th to 6:25 a. m. of the 27th. The total precipitation was 3.07 inches.

By careful watching, the alto-stratus clouds on the 27th at sunset were observed to be moving from the unusual direction of southeast and extremely slowly. The direction of these clouds, the heavy rain and mild temperature of the 27th seemed to be explained by a strong overhead current of warm air, mixing with the surface wind and raising the temperature below, for only a few miles north there was snow with a temperature around 20° F. and below freezing at localities farther south. The pressure was irregular, up and down, a great struggle going on, as if the low pressure were trying to move north or northwest, but was being prevented by too strong a high pressure. The rain and strong gusts came as the pressure dipped and as the wind backed, but slackened as the pressure rose. Although the low pressure was forced very slowly out to sea, yet it ate up the strength of its stronger opponent.

The highest wind in the city as recorded by the station anemometer was 38 miles an hour from the northeast at 9:54 a. m. of the 27th, while fishermen and boat captains estimated it as 60 miles or more at the beach, stating that it was one of the roughest and highest winter seas in many years. The winds were noticeably gusty and caused peculiar whirls like waterspouts in the Cape Fear River similar to ones observed by the captain of the cutter *Seminole* on the Pacific coast. The beach, which is one of the finest in the Southeast, underwent a terrific bombardment, the combination of high tides and great rollers cutting into some of the sand dunes at the northern end. These bulwarks of defense were sliced into as by a snowplow, and the sand on the beach was pounded hard like a cement floor. Concrete piers, iron pipes, stoves, beds, and even a large brick oven were carried like chips up the beach, showing the enormous force of the tide and breakers The beach has undergone severe pounding before, but not for a good many years has it been subjected to such a test. The damage was considerable to property, but not beyond repair. It is believed that wind and tide will build up the beach as it has done before, and steps have been taken to permanently preserve it by means of jetties at strategical points.

DUST CLOUD OVER DREXEL, NEBR., JANUARY 15, 1921.

By H. L. CHOATE, Observer.

[Weather Bureau, Drexel, Nebr., Jan. 25, 1921.]

That haze is sometimes produced by dust aloft was proved at this station on January 15, 1921. Although the air near the surface remained clear, the kite flight of that date showed evidence of a considerable dust cloud between 900 meters and 2,200 meters above ground.

In making the flight 3,100 meters of wire were reeled out. This wire was wiped clean as it came off the reel. The flight was delayed by engine trouble and the kites remained stationary for over an hour at the farthest point out. They were then reeled in slowly by hand. There was, therefore, a long period of time in which dust could accumulate on the wire and kites. On reeling in, a fairly heavy coating of light brown dust was found on the wire from 1,800 meters to the head kite. When rubbed off with the fingers, this dust felt smooth like clay, showing that the particles were very fine.

By computing the height of the wire at 1,300 meters (the difference between 1,800 meters and 3,100 meters) it was found that the lower limit of the dust-laden air was about 900 meters above ground. The dust cloud probably extended above this point a few hundred meters. Its upper boundary could not be determined exactly because the kites were reeled in so slowly that dust would accumulate on the wire even though the air at the higher levels remained clear. The kites were partially obscured when about 1,000 meters high and became nearly invisible after reaching 1,500 meters.

Cirro-stratus [really dust (?)] clouds from the northwest covered the sky throughout the flight. These clouds were creamy white in color and their outlines were indistinct.

In the following table are given the free-air data for the flight of January 15, 1921.

Time (90th Mer.).	Surface.			Aloft.			
	Temperature.	Humidity.	Wind.	Altitude.	Temperature.	Humidity.	Wind.
	° C.	Per ct.	m. p. s.	Meters.[1]	° C.	Per ct.	m. p. s.
8:04 a. m.	−7.6	91	SSE. 6.3	400	−0.3	46	SSW. 14.5
8:14 a. m.	−7.5	92	SSE. 5.3	1,000	4.2	38	W. 17.6
8:28 a. m.	−7.7	91	SSE. 5.3	1,600	−1.8	56	NW. 14.5
8:45 a. m.	−7.2	86	SSE. 4.4	2,200	−6.8	78	NW. 29.0

[1] Altitude above ground.

The above record shows that a temperature inversion of 11.7° C. occurred at the 1,000 meter level. The dust probably occurred in this inversion and for a short distance above and below. Above the inversion the

temperature fell at nearly the adiabatic rate for dry air. The state of stable equilibrium below the inversion point would probably tend to confine the greater part of the dust to a stratum of air of limited depth.

The morning weather map of January 15 showed a trough-shaped LOW extending from British Columbia to Kansas, with the lowest sea level pressure, 29.35 inches, at Helena, Mont. The pressure was also low, 29.2 inches, over the Gulf of St. Lawrence. Between the two LOWS was a ridge of relatively high pressure extending from east of Winnipeg to the Gulf of Mexico. Temperatures in this HIGH were low, ranging from $-10°$ F. north of the Great Lakes to 40° F. along the eastern Gulf coast. Cheyenne, Sheridan, Rapid City, and Denver reported temperatures close to 50° F. with wind velocities between 20 and 34 miles an hour. Stations in Iowa reported zero temperatures. There was, therefore, a difference in temperature between the eastern and western stations of about 50 degrees.

Kansas and the eastern half of Nebraska had received precipitation within the preceding 48 hours. Undoubtedly the ground was wet for several hundred miles west and southwest of the station. This condition would prevent the formation of dust in the vicinity of Drexel. It is believed that the high wind drove the dust into the air somewhere along the eastern slope of the Rocky Mountains, probably in Colorado or Wyoming. The altitude of Denver, Colo., is about 1,200 meters greater than that of Drexel. As the warm air flowed east along the gradient of the LOW it moved into a region of lower temperature. This condition compelled the warm west wind to blow above the colder south wind without mixing with the latter. The dust cloud, therefore, passed over this station at practically the same altitude above sea level as that at which it originated.

Such a condition is often observed in the lower strata at this station in connection with smoke clouds. It usually occurs as the lower wind blows from an easterly direction immediately after the passage of a high pressure area. Smoke from the city of Omaha, about 20 miles east-southeast of Drexel, can then be seen moving toward the station in a thin sheet a few hundred meters above ground. Kite flights made under these conditions always show a temperature inversion from the ground to some altitude above the upper surface of the smoke.

FURTHER EVIDENCE AS TO THE WESTERN ORIGIN OF DUST WHICH FELL IN CENTRAL STATES, FEBRUARY 12-15, 1919.

In an article on "The Great Cyclone of Mid-February, 1919," in the October MONTHLY WEATHER REVIEW (pp. 582-586) there was a brief discussion of the character of the dust collected at Des Moines, Iowa, samples of which had been examined by Mr. Jacques W. Redway of Mount Vernon, N. Y. Since the publication of that article, Mr. Redway has written to the author telling of further examinations which he has made. He says, in part: "It was not until I had received the last of half a dozen samples that I was enabled to designate its character. The last sample, which was coarse, showed that the substance was magnetic oxide of iron, Fe_3O_4, and not metallic iron. In other samples the substance so closely resembled smeltery dust that I was deceived. The dust was very clearly from the Rocky Mountains." The article above referred to stated that it was probable that the small iron particles were of local origin, perhaps from foundries in the vicinity.—*C. L. M.*

THE OBSERVATION OF DUST FALLS.

By ERIC R. MILLER.

[Presented before the American Meteorological Society, at Chicago, Dec. 28, 1920.]

[Author's abstract.]

Observation of the frequence and extent of dust falls and collection of the dust for examination are important services that the meteorologist can render the geologist, soil physicist, and plant pathologist.

Questionnaires sent out on the occasion of dust falls brought replies indicating that less than 10 per cent of the official and cooperative observers had noticed the dust.

This paper describes the appearance of rain and snow containing dust, and suggests methods of separating the dust without destroying living organisms, driving off volatile constituents, or contaminating the sample.

DISCOLORATION OF SNOW IN NORTHERN NEW YORK.

That the atmosphere in northern New York is very clean is proved by the pure whiteness of the snow, even after it has remained on the ground for a long time. At Alexandria Bay, where only hard coal is burned and there is no railroad closer than 6 miles and no factories closer than 30, there is no reason why the snow should be other than dazzling white. However, for all this, it has often come to my notice that there is a faint brownish tinge to the snows that come with the south and west winds when the temperature is near or a little above the freezing point, making a strong contrast with the extreme whiteness of the snows which are brought with the cold northerly and northeasterly winds. For instance, we will have a snow from the north, then a few days later there will be a rise in temperature with southerly or westerly winds, and with it snowfall. This snow has a dirty appearance as it lies upon the snow that fell before it. It is not always that snow with these winds is discolored. Is it not possible that the discoloration of the snow is due to the higher temperature at which it is formed? This brownish snow is generally in very large flakes and often mixed with snow pellets or soft hail (graupel), while the snow from the north is of finer texture and drier. As far as the eye can observe the brownish snow seems as clean as the other. I am curious to learn the cause of this phenomenon.—*Douglas F. Manning.*

DISCUSSION.

There would seem to be no reason to expect a difference in color on account of any difference in the crystals or the amount of water they may have. The most obvious explanation that suggests itself is that the smoke from the industrial cities south and southwest of Alexandria Bay makes the snow dirty, crystallization taking place perhaps directly on the smoke particles, and thus bringing them to the ground. On rare occasions the snow there may be discolored by dust carried from the Great Plains. A chemical analysis of this "dirty" snow would be interesting, and would reveal the cause of its discoloration.—EDITOR.

NOTE IN REGARD TO THE CLINGING QUALITIES OF SNOW.

Other things being equal, the clinging quality of snow will depend upon the form of the snowflake. This was exemplified at Binghamton, N. Y., on February 11, 1921.

The snow fell gently, without wind, from about 8:30 p. m. of the 10th to during night a. m. of the 12th, but the major portion of the snow had fallen by 8 a. m. of the 11th, and even the smallest twigs held a goodly share. Spaces as wide as 10 inches were bridged across and bunches of snow remained in the trees for three days. The weight of the snow, however, was small and little damage was done. No limbs of trees were broken, but a few electric wires came down. Country roads were not blocked to automobiles.

During the fall of snow the temperature remained steadily at 32° F.

The quite unusual clinging quality of the snow was due to the fact that the crystals were straight, fuzzy rods averaging about one-sixteenth inch in length and these, on reaching a suitable support, clung together, forming a tenacious blanket.—*John R. Weeks.*

SNOW ROLLERS.

AVON, N. Y., *February 9.*—When Peter Finigin went out to do the chores one morning recently he was mystified by the sight of a large number of huge snowballs scattered over his farm. On the 20-acre field there were hundreds of them, ranging in size from 6 to 18 inches in diameter. Leading up to each snowball was a streak of bare ground showing the distance it had traveled in forming.

Mr. Finigin and neighbors who gathered to study the odd spectacle decided that the wind, which had blown a gale the night before, had whipped up small particles of "good packing" snow and started them down the field, some of the particles gathering up additional snow until balls had been formed that were too heavy for the wind to move farther. All the paths of the snowballs were in the same general direction that the wind had been blowing.

To record the unusual freak of wind and snow, Mr. Finigin sent for the correspondent of a Buffalo newspaper, who counted more than 1,000 snowballs of more than 10 inches in diameter.—*Washington Evening Star,* Feb. 9, 1921.

BIBLIOGRAPHIC NOTE.[1]

* * * The most extensive account of snow rollers in the English language is that given in the *Quarterly Journal* of the Royal Meteorological Society, volume 34, 1908, pages 87–96. This is mainly a compilation of accounts of the phenomenon previously published in scientific books and journals, and is illustrated. Some of these accounts appeared in the MONTHLY WEATHER REVIEW.[2]

Probably the most important contribution to the subject of snow rollers is the article, "Schneewalzen," by Rudolf Meyer, in Korrespondenzblatt des Naturforscher-Vereins zu Riga, volume 52, 1909. This gives a list and analysis of all cases known to the writer between the years 1808 and 1909, and is accompanied by a bibliography which lists 35 previous papers on the subject in several languages.

Snow rollers were observed in Morris County, N. J., in January, 1809, by Rev. D. A. Clark, when it is stated that "the whole landscape was covered with snowballs, differing in size from that of a lady's muff to the diameter of 2½ or 3 feet, hollow at each end to almost the very center, and all as true as so many logs shaped in a lathe."—*C. Fitzhugh Talman.*

[1] Reprinted from *Scientific American*, New York, Mar. 15, 1913, p. 243.

[2] Dec., 1895, **23**:465; Jan., 1898, **26**:20; Mar., 1899, **27**:100; July, 1906, **34**:325–326; Feb., 1907, **35**:70.

OUR INVOLUNTARY CLIMATIC TRAVELS.

(WITH SPECIAL REFERENCE TO THE WARM WINTER OF 1920-21.)

By JOSEPH BURTON KINCER, Meteorologist.

[Weather Bureau, Washington, D. C., Mar. 2, 1921.]

The temperature of the atmosphere to which we are subjected, from day to day, plays an important rôle in our everyday life, particularly in so far as our bodily comfort when we are out of doors is concerned. Most of us do not relish extreme temperature conditions, and a considerable portion of our energy is expended in an effort to keep cool in hot, summer weather, and to keep warm when it is cold.

To escape the extreme temperature conditions of winter and summer, many people migrate yearly from north to south in winter and from south to north in summer. In northern latitudes they turn southward as the rigors of winter set in to sojourn until the gentle zephyrs of spring are due in their home community. Again, when the heat of summer begins in central and southern climes, all roads lead to some cool summer resort.

While some people thus bodily change their place of residence to enjoy climatic environments different from those usually experienced at home, many others, and much the greater portion of our population, either for reasons of choice, or for those beyond their control, stay at home. These latter, however, practically never stay at home climatically. They travel regardless of the press of business or the condition of their purse, but are not affected by increased railway or Pullman fares, for the figurative weather train furnishes free passage.

We are often handicapped, however, by reason of the fact that the science of meteorology has not, as yet, reached that degree of excellence where it is possible to forecast, with approximate certainty, in which direction, north or south, we will be transported to spend the season. To this end, however, the Weather Bureau is engaged in scientific investigations, to ascertain if seasonal schedules can be made. If this can be done our plans can be made accordingly, often at great economic advantage.

While we can not yet tell definitely in advance where our climatic season abode shall be, after we have enjoyed or deplored our involuntary weather trip, and have spent the winter or the summer either north or south of home, climatically, we can then consult the Weather Bureau records and determine just where we have been.

Such expressions as "It wasn't necessary to go to Florida this winter to enjoy a pleasant climate, for the weather here has been delightful" have been frequently heard recently. These suggest the questions, "How far south, from the standpoint of climate, did we really spend the winter just closed?" "Did we go as far south this winter as in some previous years?" "What is the farthest point south we have ever climatically spent a winter?" The answers to these and similar questions with regard to the summer season may be of interest, especially to those who have never given much thought to the fact that a

change in temperature conditions is equivalent, climatically, to an actual journey, either north or south, depending upon whether the prevailing weather at the point under consideration is colder or warmer than the average for that particular place. If we consider the questions from the standpoint of the average temperature of individual months, our weather travels are usually somewhat more extensive than when we consider a season, such as a winter or a summer, as a whole; the monthly variations, in turn, depend upon our daily excursions, being the resultant, or average of the latter.

The average or climatic temperature in the United States increases from north to south. East of the Rocky Mountains, where topographic influence is small, this increase is quite uniform. In the winter season it is pronounced, but is less rapid in summer. For winter the normal temperature varies from slightly above zero along the north-central border of the country (in northeastern North Dakota and northwestern Minnesota) to about 53° along the Gulf coast. In summer the increase is much less rapid. In general, an increase of 1° in the normal temperature in winter from north to south corresponds to a distance of about 27 miles. In descending the Mississippi Valley in summer 1° increase in normal temperature covers about 68 miles in the northern portion of the valley and about 100 miles in the central, while from Memphis southward the ratio is more than 500 miles for 1° of temperature. In the Atlantic Coast States the increase for 1° is about 55 miles in the northern, 85 in the central, and 150 miles in the southern portion. With these data available and with a knowledge of the normal temperature for a given place and the actual condition for a given time we can readily determine just how far north or south we climatically spent any summer or winter, individual month, or even a day.

The winter just closed (December, 1920–February, 1921) was characterized by a remarkable and persistent mildness in all sections of the country east of the Rocky Mountains. It therefore happened that not only those who make it a practice to go South for the winter carried out their usual program, but the Nation-wide weather train, which operates from every locality in the United States, carried the entire population southward, not all of us to Florida, of course, but nevertheless to a considerable distance in that direction.

Figure 1 shows just how extensive our travels have been in the different sections of this area. Heavy lines have been drawn along latitudes 32.5°, 37.5°, 42.5°, and 47.5°, representing the four major 5° belts of latitude across the eastern United States. The arrows to the southward of each line show the average extent of the southward climatic journey for the localities within each 5° belt of latitude represented. For example, people in central North Dakota, climatically speaking, spent the winter near the South Dakota-Nebraska boundary line; those at Sioux City, Iowa, at Kansas City, Mo.; Chicago, in southern Indiana; southern Indiana in northern Tennessee, and Washington, D. C., in southern Virginia. The broken line to the north of each heavy line indicates in like manner the relative climatic shift for the previous winter, 1919–20, mostly in the opposite direction. That winter was considerably colder than usual in all central and northern districts from the Mississippi Valley eastward, and consequently persons living in this territory were not so fortunate as in the winter just closed. For example, for the winter of 1919–20, Richmond came north, climatically, to Washington to spend that winter and went south to Raleigh, N. C., for the one just closed.

While the winter of 1920–21 will be classed as one of the mildest on record east of the Rocky Mountains, it was not a "record breaker," and several others in the last 50 years compared favorably with it. In the central and northern sections of the country east of the Rocky Mountains the winter of 1877–78 still holds the 50-year record for mildness, although it came dangerously near surrendering that distinction this time. St. Paul, Minn., spent the winter of that year at Hannibal, Mo.; Bismarck, N. Dak., at Omaha, Nebr.; and Chicago at Cairo, Ill. From the Ohio Valley and Middle Atlantic States southward the winter of 1889–90 holds the record for mildness. In that year the figurative weather train took the people of Cincinnati down to Memphis, Tenn., and Washingtonians south to northeastern South Carolina. The farthest north Washingtonians have spent a winter climatically was in southern Connecticut, in both 1903–4 and in 1904–5.

It has been previously stated that our climatic sojourns, when considered on a monthly basis are frequently some-

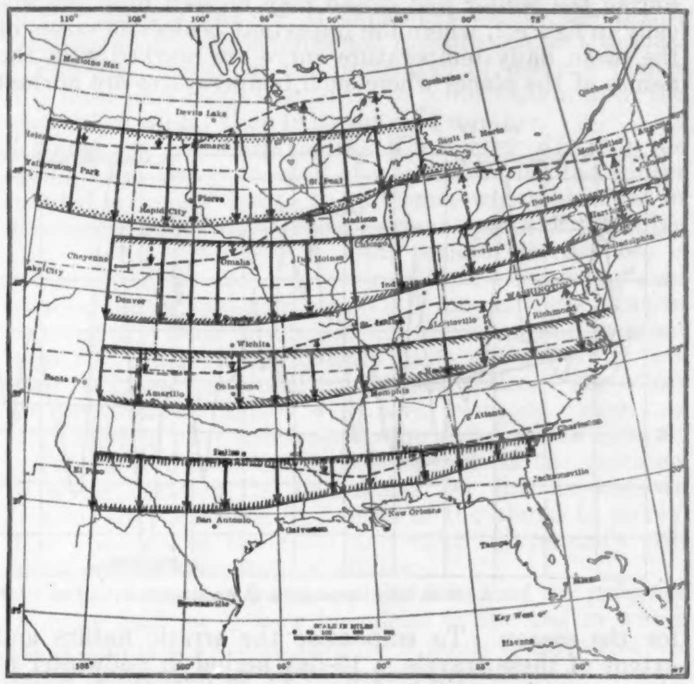


FIG. 1.—Climatic geographic displacements (north and south) of winters of 1919-20 (dashed) and 1920-21 (solid) from the normal.

what more extensive than for a season as a whole. In this connection it may be of interest to point out a few of the most pronounced cases of record. For that purpose Washington, D. C., and St. Louis, Mo., will be used as a basis, considering only January and July, or the midwinter and midsummer months. The farthest south St. Louis has spent January was at Greenwood, Miss., in 1880; and the farthest north was near Dubuque, Iowa, in 1918. Washingtonians sojourned in northeastern South Carolina in January, 1890, and in extreme southwestern Maine in 1918. The extremes for St. Louis in July were southeastern Minnesota, in 1891, and beyond the Gulf coast in 1909. Northeastern South Carolina appears to be the southern limit for Washington for monthly visits as well as for seasonal. We visited there during July, 1872, while for July, 1891, we went north to a real summer resort, Lake George, N. Y.

These relative monthly and seasonal thermal shifts alternating from north to south, are the resultant or average, of our daily climatic excursions. The basic, funda-

mental temperature data are the daily values, and when these are considered in their relation to the seasonal normal, they furnish an even more striking and interesting picture of our migrations between warmer and colder latitudes. Some one has described the average, or normal, meteorological condition as "that which never occurs"; certainly it seldom occurs.

Unlike the poet, the meteorologist has no special license to indulge in figurative speech, but with the indulgence of the reader, we shall at this point digress somewhat from the orthodox phraseology usually employed in scientific explanations of natural phenomena, and give a brief paraphrased description of our daily climatic travels during a short midwinter period of the present year.

Let us draw a mental picture of all Washington, D. C., as being aboard a weather train that transports us alternately between northern and southern latitudes as the temperature from day to day varies from warmer to colder or vice versa. The major travels for this train during the winter just closed may be seen most graphically in figure 2, where the important peaks and crests of the mean daily temperature curve are marked with the names of the places where such temperatures are normal

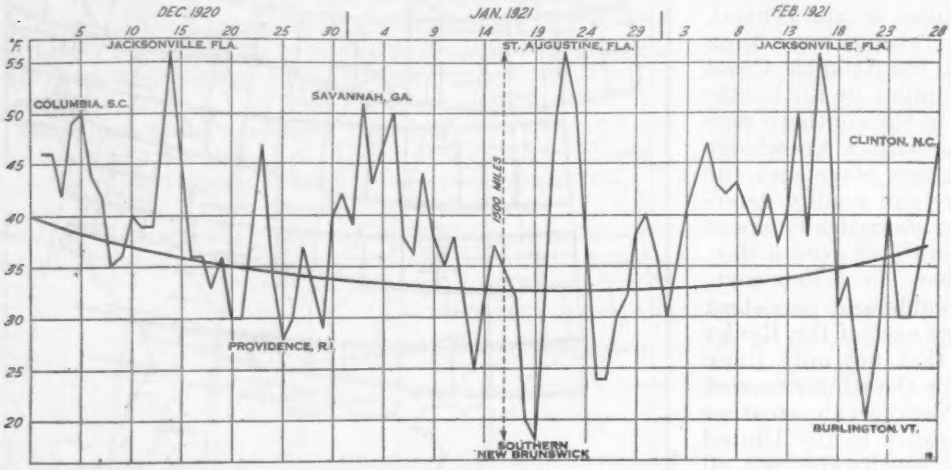


FIG. 2.—Mean daily temperatures at Washington, D. C., Dec. 1, 1920, to Feb. 28, 1921.

for the season. To emphasize the erratic nature and extent of these travels, a 10-day period in midwinter of the current year will be followed in detail; the train will be considered "at home" when the temperature for the day at Washington is normal for the season. Starting from home on January 17, 1921, our train headed for the North and did not stop until Eastport, Me., was reached on the 18th. The following day a short reconnoitering trip farther up the coast in New Brunswick was made. We then turned southward, reaching Washington on the 20th. Only a one-day stopover was made at home, however, and our journey was resumed toward the South.

The 21st was spent at Wilmington, N. C., while St. Augustine, Fla., was scheduled for the following day. Remaining in this well-known winter resort only one day, the return northward was begun; Savannah, Ga., was passed on the 23d and Richmond, Va., on the 24th. At this point more steam was applied and the following day we appeared in southwestern Maine. After remaining there two days, another southward journey was begun, passing through Washington on the 28th.

Fort Pierce, Fla., about 75 miles north of Palm Beach, is the farthest south Washingtonians have ever spent a day climatically in January. An outing has been enjoyed at this point twice in the last 50 years, on January 12 and 13, 1890, and on January 27, 1916.

It is obvious that the conductor of this figurative weather train has anything but a fixed schedule, and apparently without rhyme or reason, changes his plans on the spur of the moment and acts accordingly, absolutely refusing to take the public into his confidence. Now, here is where the official forecaster of the Weather Bureau comes to our assistance. Each and every community in the United States is the headquarters for a weather train that is constantly moving climatically north or south. The schedules are controlled by physical laws, and the forecaster must determine each day in the year just what the schedules for the following day or two are to be for each train operating under this vast transportation system. This determined, he announces them for the benefit of the public that they may make their plans accordingly.

The question, however, is not even so simple as here indicated, for at one time Dame Nature may decide on considerable uniformity of movement and order all trains over a large section of the country in the same general direction, either north or south; while at other times, no such uniformity exists and even in near-by localities the train movements may be oppositely directed. In the first case, the whole system may be viewed as being operated under orders issued from a central office by a general train dispatcher, with a definite plan of coordinated movements, while in the second case the matter is apparently left to the whims and wishes of the conductor of each individual train. A large percentage of the forecaster's failures of verification occur under the latter conditions. Viewed in this light, his job is by no means an enviable one, and we must agree that a verification record averaging 85 to 90 per cent perfect, the record he is making to-day, is creditable.

One week ahead is now about the limit of a reliable schedule. Imagine, if you can, what a schedule weeks in advance would mean to us stationary weather travelers.

OPEN WINTER AND PLANT LIFE.

[Reprinted from the *Philadelphia Public Ledger*, Jan. 5, 1921.]

An open winter, such as is being experienced in this locality this year, is generally more injurious to plant life than it is beneficial, in the opinion of Dr. John W. Harshberger, professor of botany at the University of Pennsylvania.

Certain plants, according to Dr. Harshberger, have been so protected and planned by nature that they are unaffected by such unusual weather, and in other cases no definite harm is done unless the warm period lasts a long time.

Warm weather in winter is not especially injurious to plant life unless it starts dormant buds to swell and burst open, thus exposing the delicate leaf and flower tissues to the action of the succeeding cold spell.

There are many native plants, trees, and shrubs which are not ordinarily stimulated to development by warmth

in the winter season because they have been long adjusted to the particular climatic conditions of eastern North America. Meteorologists tell us that this exceptional weather has had a counterpart in the past, and as our native plants have existed for many thousands of years, there is no doubt but that they have many times been exposed to conditions to be found to-day.

Then there are many plants which normally blossom early in the year before actual spring conditions come. In this category are the skunk cabbage, the witch hazel, and the like. These plants are not especially injured by periods of cold weather succeeding an open winter.

In addition, there are a few plants introduced from Europe and other countries, such as the Japanese witch hazel, the snowdrop, the winter aconite, and the Christmas hellebore and others, which frequently flower in January succeeding a few days of open, warm weather. When this warm spell is in turn followed by snow, the winter aconite and the rest of these garden species are completely covered up, and when that snow melts they are found to be uninjured.

Snow is good protection to plants.—In fact, snow is one of the best protections that plant life has against the rigors of winter. A cold, snowless winter, with high winds and low temperature, is much more destructive, generally speaking, to plant life than a winter with a heavy snowfall. This ability of the snow to act as a blanket for plants has been repeatedly shown in the north of Italy, where an early spring snowfall will do less damage to crops than a late, snowless period of cold weather accompanied by high winds and bright sunlight.

During the early months of 1920 there was a very interesting exemplification of the action of a frozen soil and cold weather. The soil was frozen to the depth of more than a foot and later a heavy snowfall came, which partly melted and was again frozen to form an icy sheet several inches thick. This was followed by an extremely cold spell with strong winds and bright sunlight, which, however, was counteracted by the blanket of snow and ice.

It is a fact, however, that hardly any season in the annals of Philadelphia horticulture has been more trying and detrimental to conifers, rhododendrons, and other evergreens than was last season. Rhododendrons were destroyed by thousands where gardeners had not had the forethought to cover the roots with a heavy mulch of forest leaves and other litter. The reason for this destructive action was the fact that during the winter rhododendrons and kindred species are constantly giving off considerable amounts of moisture, and this loss of water from the surface of the plant is increased by bright sunlight and strong winds. The water thus given off during an ordinary winter is obtained from the soil, but in 1920 the soil was frozen to such a depth that the roots were unable to obtain the water necessary to replenish the loss from the surface, and consequently the plants dried up, their leaves turning brown and withering, with a result as disastrous to the tops of the plants as a fire would have been.

Many plants get rest in winter.—The period of winter is advantageous to many plants, which enter a period of rest at this time, giving an opportunity for the ripening of the wood and the maturing of the buds. This has a beneficial result on the gradual preparation of the underground parts of the plants for the burst of spring growth. In fact, some bulbs and some seeds will not begin growth until they have been subjected to either the cold of winter or the drought of such climates as we find in the great deserts.

This feature is known as the "rest period," and for this reason an open winter, in giving no such opportunity, is sometimes succeeded by a less vigorous growth the following spring, as contrasted with a winter of abundant snowfalls and normally low temperatures, which produce the necessary ripening effect on buds and other dormant parts of the plant.

A cold spell is particularly dangerous to plant life after a period of warm rains with open grounds, because most plants absorb water during the winter and become gorged in their overground parts. A subsequent freezing is liable to burst the delicate tissues of the plants. Frost cracks on trees are a good example of this danger, and they are quite likely to result, particularly if the cold spell is followed by bright sunlight. Without the latter the water which is frozen out of the plant tissues may be absorbed back again so slowly into the living cells of that plant that the destructive action is prevented; but with bright sunlight the ice is expanded within the plant, resulting in the aforementioned rupture of plant tissues.

For this reason, in the protection of delicate plants it is more important frequently to protect them from the sunlight in winter than from the cold weather.

Plants safe if buds are closed.—The danger of frost in the spring or in any open spell of weather during the winter months is largely due to the influence which heat has in expanding buds and starting dormant parts of plant life into activity. As long as buds remain closed there is ordinarily little cause for worry from succeeding cold weather, but if the warm period is of long enough duration to cause the buds to expand the following cold weather generally destroys the delicate parts within, which are then no longer protected by the bud scales. The latter are provided by nature with cork, resin, or cottony or silky hairs to offer resistance to the action of the climate.

The most destructive action in buds is the entrance of water between the bud scales, for this expands in freezing and tears the frail parts of the plants to pieces. The presence of the resin and other of nature's aids helps prevent this state of affairs.

On the other hand, it is equally true that the presence of frost and ice is very beneficial to the soil in which many plants are found, because it tends to pulverize the larger soil particles through the expansion of the ice particles. As a consequence, soil exposed to the action of frost is mellowed and made fit for the growth of subsequent crops.

A final destructive effect of an open winter as contrasted with a normal one is the fact that many plants are stimulated unduly, thus shortening their lives, because the reserve foods are used up before the rapid demand of the plant comes for the expenditure of such stored materials.

FREEZING OF FRUIT BUDS.

By FRANK L. WEST and N. E. EDLEFSEN.

[Extracted from Journal of Agricultural Research, Jan. 15, 1921, Vol. XX, No. 8, pp. 655-662.]

[Authors' summary.]

(1) Efficient orchard heating demands an economical use of labor and fuel and requires knowledge of the temperatures that cause injury to the buds.

(2) This paper contains the results of seven years' experiments in freezing 24,000 apple, peach, cherry, and apricot buds, together with a record of the natural freezes

that occurred in the orchards near Logan, Utah, during the same period.

(3) Ben Davis apple buds in full bloom have experienced temperatures of 25°, 26°, and 27° F., without injury, but 28° usually kills about one-fifth. Twenty-nine degrees or above are safe temperatures. Twenty-five degrees kills about one-half and 22° about nine-tenths. On several occasions, however, apples matured on branches that experienced 20° when the buds were in full bloom.

(4) With Elberta peach buds in full bloom, 29° F., or above, are the safe temperatures, because even though occasionally 26°, 27°, and 28° do no damage, yet on most occasions 28° will kill from one-fourth to one-half. Twenty-six degrees kills about one-half of them and 22° about nine-tenths. Temperatures as low as 18° have failed to kill all of them.

(5) With sweet cherry buds in full bloom, 30° F. is the safe temperature; 25°, 26°, 27°, 28° have done no damage; but 29° usually kills about one-fifth. Twenty-five degrees usually kills about one-half, and when the buds were showing color 22° killed only two-fifths of the buds.

(6) Sour cherries are hardier than the sweet varieties. When the buds were showing color 23° did not harm them, and when they were in full bloom 26° killed but one-fifth and 22° only two-fifths of them.

(7) With apricots 29° is the safe temperature; 26° and 27° killed about one-fifth and 22° killed one-half. They are fairly hardy, but they bloom so early that they are frozen oftener than any of the other fruits studied in the experiments.

(8) The foregoing figures refer to the buds when in full bloom. Starting from this stage, the earlier the stage of development the hardier the buds are; and in general, when the fruit is setting the injury is from 5 to 10 per cent more than when they are in full bloom.

(9) Sour cherries are the hardiest, and then follow in order apples, peaches, apricots, and sweet cherries.

(10) The fact that the same branch of buds will on one occasion experience 27° with 25 per cent injury and on another occasion take the same temperature with no injury is no doubt due to the fact that the juice is contained in capillary cells and supercooling results—that is, the buds are cooled below the freezing point of the juice without the freezing taking place. The great difficulty of killing all the buds even at extremely low temperatures is due to the same cause, together with the fact that the cell sap may be very concentrated. Differences in the hardiness of the different kinds of buds and also of the same buds at different stages of development is due to differences in quality and concentration of the cell sap.

SEVERE HAILSTORM IN NEBRASKA.

HARRY G. CARTER, Meteorologist.

[Weather Bureau, Lincoln, Nebr., Dec. 22, 1920.]

On Friday, July 16, 1920, there occurred in Antelope and Boone Counties, in northeastern Nebraska, an unusually severe hailstorm.

The center of the path of greatest destruction extended from south of Royal and Brunswick, in Antelope County, to a point just east of Neligh, thence southward directly through Oakdale, east of Elgin, Petersburg, Loretto, Albion, and Boone, through St. Edward and between Fullerton and Genoa to the Platte River, a distance of nearly 70 miles. The area over which hail fell varied from 1 mile to 6 miles in width. No reports were received of hail from stations south of the Platte River.

In the area of greatest destruction portions of farms were swept nearly clear of vegetation. Small grain was pounded flat to the ground and some fields were left nearly bare, and in places it was difficult to tell just what crop had occupied the field before the storm struck. Here and there nothing remained of corn but battered stalks from a few inches to a few feet in height. Trees were divested of foliage and bark stripped off on the side facing the storm. The high wind uprooted trees and wrecked farm buildings, while the hail broke nearly all the windows on the north side of farm houses and buildings and many on the east side, besides damaging many roofs so badly that the rain poured through and damaged the interior. An excessive downpour caused a few streams to overflow their banks so that in places the devastated region suffered loss from floods in addition to loss from hail and wind.

Some farmers in the stricken region lost a large portion of their growing crops. A few sowed millet, cane, or buckwheat in their storm-swept fields. A number found it necessary to dispose of their surplus hogs and cattle as it was impossible to provide feed for them.

The greatest damage occurred in the region adjacent to Oakdale, in Antelope County. North of Oakdale but a relatively small area suffered loss, while to the southward from Oakdale to a point nearly east of Albion, in Boone County, there was considerable damage to various crops. East of Albion the hailstones were smaller, the wind velocity less, the rain fell at a slower rate, and the damage to crops was consequently less than to the northward. From here southward the storm gradually decreased in intensity, and south of the Platte River no hail was reported.

The hail was an accompaniment of a thunderstorm of unusual severity. The wind at places approached hurricane strength, but at no time was there any indication of tornadic action, the damage by the wind in every case reported being the result of a straight blow. All reports state that the greatest damage to buildings by hail was on the north side, although at some places the east side suffered nearly equal damage.

The hailstones varied in size from $\frac{1}{2}$ inch to more than $2\frac{1}{2}$ inches in diameter, and were mostly round. Some observers, however, reported hailstones that were "flattened spheres" and "irregular chunks of ice." The surfaces of the hailstones were mostly smooth, although some were rough. No marked protuberances were noticed.

The hail began to fall soon after the beginning of the rain, the interval varying from a few minutes to more than 30 minutes, the average time being somewhat less than 15 minutes. Rain fell from 30 minutes to $2\frac{1}{2}$ hours, the time being less and the rate of fall greater in the northern portion of the area. Hail fell from 15 minutes to an hour, at most places the time being less than 30 minutes. It continued longer in the southern end of the belt than in the northern.

Neligh was on the western edge of the storm. Here rain fell from 2:50 p. m. to 3:20 p. m., and although hail fell for 20 minutes (from 3 p. m. to 3:20 p. m.) the hailstones were not unusually large and caused no material

damage in the city, although crops were damaged 1 mile to the east, the damage extending over an area from 1 mile to 3 miles in width. A high wind accompanied the storm and trees were uprooted and telephone and electric light wires were blown down by the wind or carried down by falling branches of trees. A rainfall of 2.13 inches was recorded in 30 minutes, flooding the town. A race meet was in progress when the storm struck, and so suddenly did the storm come up that none of the people in the park had a chance to leave. A big tent and many booths and a ferris wheel belonging to a carnival company were wrecked, but no lives were lost.

The storm had increased in intensity by the time it struck Oakdale at 3:15 p. m. Here 5.80 inches of precipitation, including rain and melted hail, fell in 45 minutes, turning streets into raging rivers several feet deep in places and flooding nearly every basement in the business part of the town, the water even running into the street doors of some of the stores. The municipal water plant was flooded and was shut down until 3 p. m. Sunday, the 18th. Hailstones from 1 inch to more than 2½ inches in diameter fell for 25 minutes. Nearly all the windows on the north and east sides of buildings and houses were broken. Holes were pounded in roofs and rain poured through in torrents, flooring the interiors. Trees were stripped of foliage and bark peeled off on the side facing the storm. A gale uprooted trees and broke telephone and electric light wires.

It was in this territory that crops suffered the greatest damage. Over a strip from 3 to 5 miles in width the destruction was nearly complete. Hailstones accumulated in drifts to a considerable depth. Authentic reports were received of hailstones lying in drifts several feet deep in protected places, requiring a number of days to melt.

A passenger train on the Northwestern Railroad leaving Oakdale at 2:50 p. m. was caught in the storm between Oakdale and Neligh and most of the windows on the north side of the train were broken.

South of Oakdale the storm decreased in intensity. At Closter, 14 miles south of Oakdale and 10 miles east of Petersburg, crops were damaged over an area about 6 miles in width, and while losses were considerable the destruction was not as complete as at Oakdale. No authentic measurements of hailstones were made, but a newspaper report mentioned the hailstones as "huge chunks of ice swept with deadly force by a high wind." Rain fell from 3 p. m. to 3:30 p. m.

East of Albion the path of the storm was 6 miles wide. Rain fell from 3 p. m. to 3:35 p. m., and hail fell for 15 minutes, beginning at 3 p. m. The largest hailstones were the size of dove eggs, although most of the hailstones were the size of bird eggs.

At Boone rain fell from 4 p. m. to 6:30 p. m., and hail from 4:15 p. m. to 5 p. m., the hailstones being the size of marbles.

At the southern end of the hail-swept area, about 8 miles north of the Platte River, rain did not begin to fall until 5 p. m. and ended at 6 p. m. Hail began to fall very soon after the beginning of the rain and continued 45 minutes, the largest hailstones being the size of goose eggs and doing considerable damage to crops.

The rain did not begin over the entire region at the same time, but began at the north end first. A line passing through places where the rain began simultaneously runs in a northeast-southwest direction, The rain area spread southeastward rather than straight southward.

It is thought this unusually severe thunderstorm did not move from the north to the south. It is more likely that it moved eastward with a front extending from northeast to southwest, the rain beginning along the entire front at nearly the same time. This would account for the northeast-southwest line of simultaneous beginning.

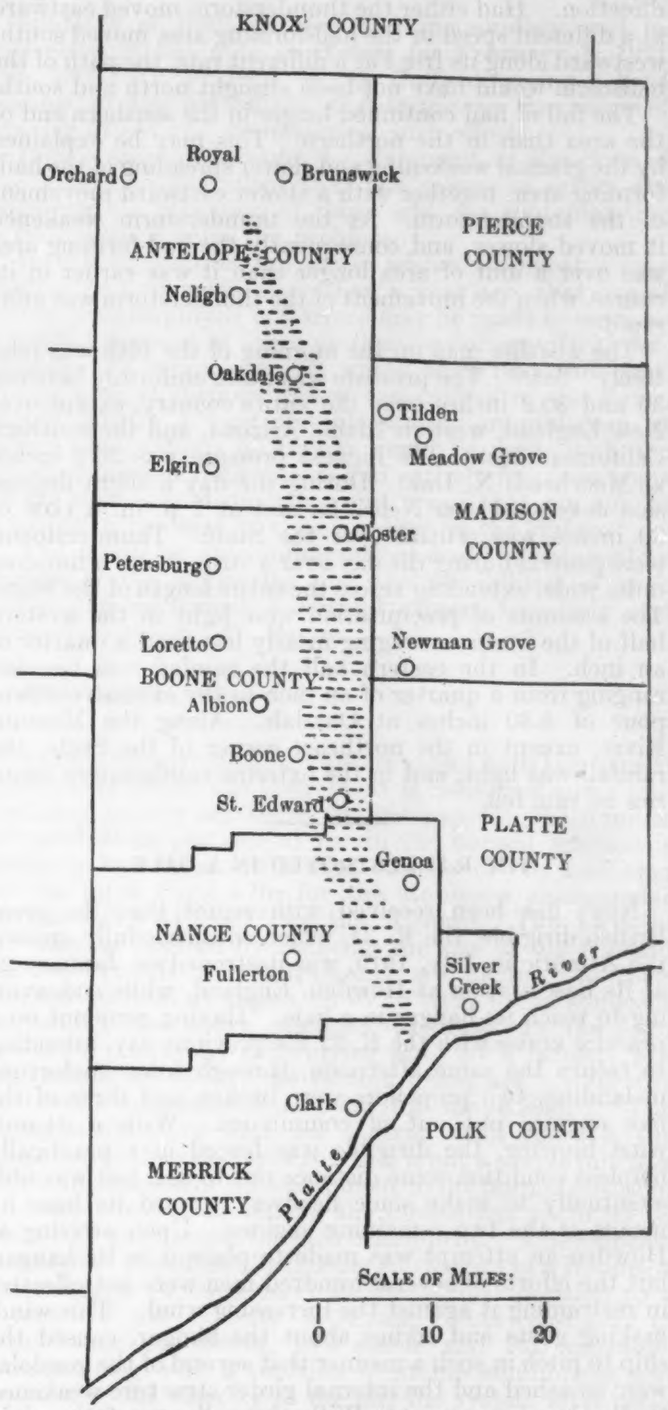


FIG. 1.—Shading indicates area over which hail fell, in severe storm of July 16, 1920, in eastern Nebraska. Growing crops were damaged more or less over a considerable portion of this area, and in places were completely destroyed.

Hail began to fall at all places in the northern half of the belt at nearly the same time, but over the southern half it began later and later as it spread southward, and at the southern end of the belt hail began 2 hours later than at the northern end.

It is very probable that hail was formed first on the extreme front side of the thunderstorm and gradually spread southwestward along its front. As the thunder-

storm moved eastward the hail-forming area was moving southwestward along its front. The ratio of the two movements was such that the resultant was a southerly movement of the hail-forming area. This would give the appearance of a hailstorm moving in a straight southerly direction. Had either the thunderstorm moved eastward at a different speed or the hail-forming area moved southwestward along its front at a different rate, the path of the hailstorm would have not been straight north and south.

The fall of hail continued longer in the southern end of the area than in the northern. This may be explained by the gradual weakening and slower spreading of the hail-forming area, together with a slower eastward movement of the thunderstorm. As the thunderstorm weakened it moved slower, and consequently the hail-forming area was over a unit of area longer than it was earlier in its course, when the movement of the thunderstorm was more rapid.

The weather map on the morning of the 16th was relatively "flat." The pressure was quite uniformly between 30 and 30.2 inches over the entire country, except over New England, western Idaho, Arizona, and the southern California coast. The highest pressure was 30.2 inches at Moorhead, N. Dak. During the day a slight depression developed over Nebraska and at 7 p. m. a LOW of 30 inches was central over the State. Thunderstorms were general during the day over a strip about a hundred miles wide, extending across the entire length of the State. The amounts of precipitation were light in the western half of the State, averaging mostly less than a quarter of an inch. In the eastern half the rainfall was heavier, ranging from a quarter of an inch to the excessive downpour of 5.80 inches at Oakdale. Along the Missouri River, except in the northeast corner of the State, the rainfall was light, and in the extreme southeastern counties no rain fell.

THE R.34 DESTROYED IN A GALE.

News has been received with regret that the great British dirigible, the R. 34, which so successfully crossed the Atlantic in July, 1919, was destroyed on January 28 at its base station at Howden, England, while endeavoring to reach its hangar in a gale. Having gone out on a practice cruise with the R. 32 the previous day, intending to return the same afternoon, through some misfortune in landing, two propellors were broken and three of the five engines put out of commission. With a 34-mile wind blowing, the dirigible was forced in a practically helpless condition some distance out to sea, but was able eventually to make some headway toward its base by means of the two remaining engines. Upon arriving at Howden an attempt was made to place it in its hangar, but the efforts of several hundred men were not effective in restraining it against the increasing wind. This wind, making gusts and eddies about the hangar, caused the ship to pitch in such a manner that several of the gondolas were smashed and the internal girder structure weakened to the breaking point. With the collapse of the rigid framework and the consequent piercing of the gas bags, the airship was practically destroyed. While mooring masts are yet in the experimental stage, it appears that in tests recently made, large rigid airships have outridden storms of as great severity as this with no damage whatsoever and without the aid of a large ground party. It is unfortunate indeed that this famous and costly ship could not have had access to such a mooring mast. While it is apparent that the reasons underlying the destruction of this ship are mechanical and could probably have been overcome with adequate equipment, such as that mentioned above, yet it furnishes a noteworthy example of the effect of weather upon aircraft and the importance of neglecting no opportunity to take account of this factor.—*C. L. M.*

ARE THE SEASONS CHANGING?

By CLARENCE J. ROOT, Meteorologist.

[Weather Bureau Office, Springfield, Ill.]

It is probably the experience of every Weather Bureau official to hear remarks similar to this: "The seasons are changing. We do not have the cold weather we did when I was a boy." With the exception of a few months in 1795, continuous temperature records have been maintained at New Haven, Conn., since February, 1780. The data used in this discussion were taken from the records of various observers from 1778 to 1872 and from those of the Weather Bureau station at New Haven from 1873 to the present.[1] The writer has averaged the annual mean temperature values by decades, with the following results:

For the 10 years ending—	Mean temperature (F.), degrees and tenths.
1790	49.6
1800	50.0
1810	50.4
1820	47.5
1830	49.3
1840	47.8
1850	49.2
1860	48.9
1870	49.1
1880	49.7
1890	48.9
1900	49.7
1910	49.7
1920	50.5

It will be noted that the warmest three periods are those ending in 1800, 1810, and 1920, and that the coldest decade immediately follows the second warmest.

Considering the individual months and the individual years, it is found that the coldest January occurred as late as 1857. The coldest February occurred 8 years after the warmest one. The coldest March was as late as 1870 and again in 1885. The coldest April was in 1874, and many years after the warmest one. In May we find a number of years with the same lowest temperature—1812, 1815, 1870, and 1882. The highest figures in June are in 1779, 1790, 1803, and 1876. In July the lowest was in 1816, with the warmest as early as 1780 and as late as 1876. The coldest August occurred 61 years after the warmest. In September the coolest months are in the earlier years, but for October, November, and December the coldest year came after the warmest year in each case.

Thus it will be seen that in nine months of the year the coldest one of record occurred after the warmest one. These figures seem to indicate very clearly that since the time of the Revolutionary War, at least, there has been no permanent change in temperature.

[1] The earlier observations are published in the *Transactions of the Connecticut Academy of Sciences*, vol. 1; they are summarized and combined with the Weather Bureau records in the *Annual Meteorological Summary for 1920*, published by the Weather Bureau office at New Haven, Conn.

REDUCTION OF A CENTURY OF TEMPERATURE OBSERVATIONS TOHOMOGENIETY.

By ERIC R. MILLER.

[Presented before the American Meteorological Society at Chicago, Dec. 29, 1920.]

[Author's abstract.]

A table of monthly mean temperatures from October, 1819, to date has been prepared for Madison, Wis. Of these, 59 years 8 months are derived from observations actually made at Madison. The period from October, 1819, to December, 1873, is covered by data from stations in Wisconsin and adjoining states at which observations were made by the Army Medical Corps, Smithsonian observers, and others.

The Madison data have been corrected to the mean of 24 hourly observations. The other data have in addition corrections for reduction to Madison. These corrections were obtained from recent observations.

The aggregate length of record from the 17 neighboring stations used is 283 years 10 months, and gives from one to nine estimates of the mean temperature for each month. Comparison of these estimates with one another and with observations at Madison, when available show that single estimates may differ 5° or 6°, but that the mean of four or five estimates is within $2\frac{1}{2}$° F.

The comparisons also show that the Smithsonian and Army thermometers were exposed to the sun at some stations. The influence of exposure nearer the ground than in Weather Bureau offices of the present day is also plainly evident. Only one case, of serious instrumental error was detected among the 18 stations considered. Many typographical errors in printed tables were found.

THE INVESTIGATION OF GRAVITY AT SEA.

Students of both geodesy and meteorology will be interested in the note in *Nature* for February 3, 1921 (pp. 732–734), by Prof. W. G. Duffield, giving a brief résumé of the difficulties of determining the value of gravity at sea and the results of such efforts.

It is gratifying to note the statement at the close of the article to the effect that the causes of errors are engaging the attention of those who are contemplating a fresh attack upon the problem.

In this connection the writer wishes to repeat a suggestion he first made more than a year ago, that one of the engines employed in warfare may be made to serve an excellent purpose in the investigations of gravity at sea, namely, the submarine. It would seem that this boat, riding a short distance below the surface of the water, would furnish a very suitable station in midocean at which observations of gravity could be made with the greatest possible deliberation and entirely free from some of the sources of disturbance and errors that can not be avoided in the case of vessels riding on the surface.

The details by which observations could be obtained by means of the submarine and the possibilities of such investigations furnish a fruitful subject for study and development.—*C. F. Marvin.*

NOTES, ABSTRACTS, AND REVIEWS.

ELECTRIC-OSCILLATION ANEMOMETER.[1]

By E. ROTHE.

[Reprinted from *Science Abstracts*, Sect. A, November, 1920, §1376.]

In cloudy or foggy weather, when observations of the upper winds by pilot balloons are impossible, an electric contact anemometer may be raised by balloon or kite, but this necessitates a double wire with the consequent additional weight to lift. The author outlines a method of using only a single wire, the cable of the balloon or kite. The anemometer is made to act as an interrupter, putting into action, at each contact, an instrument which sets up electric oscillation in the wire. These are received at the surface by a "wireless" receiving set. The velocity of the wind is deducible in the ordinary way from the frequency of the contacts. Several anemometers may be attached to the cable at different heights, each instrument emitting waves of a different length, so that any particular one may be made to register by suitably tuning the receiver at the surface. Extension might be made to other meteorological elements, and a complete "observatory" could then be raised and made to record at the surface by a single wire.—*M. A. G.*

VARIATION OF THE INDICATIONS OF ROBINSON AND RICHARD ANEMOMETERS WITH THE INCLINATION OF THE WIND.[2]

By C. E. BRAZIER.

[Reprinted from *Science Abstracts*, 1920, §1041.]

Robinson and Richard anemometers have been exposed, in an aerodynamical laboratory, to wind currents of known velocity making various angles with the normal position in which the instrument is used, and some preliminary results are noted in this paper. The number of revolutions per second (n) in the normal position is found to be related to the wind velocity (V) by a relation of the form $V=A+Bn$. for the Robinson anemometer and $n=aV+bV^2+cV^3$ for the Richard. The term in V^3 may be omitted by reducing the size of the Richard instrument. If the instruments are inclined to their normal position at angles up to 30° it is found sufficient to modify the above relations, expressed in the form $n=\phi(V)$, simply by multiplying $\phi(V)$ by a factor. For an inclination of 30° the factors found are 1.1 for the Robinson anemometer and 0.8 for the Richard. The experiments show that, for a given wind velocity, the variation in the velocity of rotation is not a simple function of the inclination of the instrument to the normal position, and the effect of increasing the inclination up to 90° is shown by an example for each instrument. A description is added of the effect of exposing an element of a Robinson anemometer (2 cups only) in the normal position to a stream of air velocity 5 m./sec. Four positions of equilibrium are found, two stable and two unstable. Commencing with a position of stable equilibrium and increasing the velocity of the air, the system after oscillating finally rotates continuously in the ordinary sense.—*M. A. G.*

DISCUSSION.

This note is important in that it indicates a method of determining true velocities from anemometers carried by kites or airplanes whose position may change more or less with reference to the wind, and from anemometers of the "windmill" type (such as Richard's) when they are oriented by vanes of different lengths.

[1] *Comptes Rendus*, May 17, 1920, 170:1197–1198.
[2] *Comptes Rendus*, Mar. 8, 1920, pp. 610–612.

A few comparisons with results obtained by other experimenters will be of interest:

W. H. Dines (1889–1893)[1] found (1) that the pressure on a flat plate decreased very little when the angle changed from normal (0°) to 45°; (2) that a self-adjusting helicoid anemometer was slightly affected by changes of direction while an air meter was considerably affected, both instruments underregistering in a wind of variable direction; (3), a pressure-tube anemometer was not affected by changes of 15° to 20° from a mean direction.

Experiments at Blue Hill Observatory (1892–93)[2] showed that "windmill" anemometers carried by vanes 80 to 120 centimeters in length recorded correctly at low and moderate velocities (below 10 m./s.) but underregistered at an increasing ratio at higher velocities, the deficiency amounting to about 20 per cent at 30 m./s. The same anemometers, on wide vanes 30 to 50 centimeters in length, recorded correctly at all velocities.

Prof. Marvin (1899)[3], while testing Robinson anemometers on a whirling machine, found that the indications of a kite anemometer making one rotation for each meter of wind were not seriously affected when the axis of the instrument deviated continuously as much as 20° from the vertical, the average of several experiments being about 4 per cent, or practically within the usual range of variation found among anemometers of the Robinson type under similar conditions.

Further results of this work are awaited with interest.—*S. P. Fergusson.*

BRIGHTNESS OF THE UNCLOUDED SKY.[4]

By M. UIBE.

[Reprinted from *Science Abstracts*, Sect. A, November, 1920, §1410.]

Describes a form of portable photometer designed for comparing the brightness of different parts of the sky. The two parts to be compared illuminate a photometer of the Lummer-Brodhun contrast type, and equality of brightness in the photometer is obtained by varying the thickness of a layer of liquid placed in the path of one of the beams of light. This liquid consists of an aniline neutral grey solution, but for light reductions of large ratio gray glasses are employed. The author has used the apparatus for determining the distribution of brightness of the clear sky as seen from a height of some 3,000 meters in Teneriffe.—*J. W. T. W.*

SPECTROPHOTOMETRY OF SKY LIGHT.[5]

By D. PACINI.

[Reprinted from *Science Abstracts*, Sect. A, December, 1920, §1552.]

Described a prolonged spectrophotometric study of the light from the sky under various conditions, as seen from Sestola (1090 meters above sea-level). The observations were made with a photometer employing an acetylene flame as standard. Curves are given for the relative intensities throughout the visible spectrum for the light from the zenith and various parts of the sky, at different times of day from dawn onwards, and under conditions of cloudiness, misty and dull. The light was found to be selective, having a decided preponderance of blue. It also appears that a very pronounced reduction in the extreme violet is associated with the condensation of aqueous vapor.—*J. W. T. W.*

COLOR AND POLARIZATION OF SKY LIGHT.[6]

By A. GOCKEL.

[Reprinted from *Science Abstracts*, Sect. A, November, 1920, §1377.]

Using a polarimeter fitted with Wratten filters, the polarization of the light from the sky is investigated for various parts of the spectrum. The intensity of the light was also measured after each observation of polarization. In the paper the results and methods of other authors are fully discussed, but the writer's own results are chiefly that on a clear atmosphere the differences in the polarization of individual colors are smaller than the errors of observation. With increasing turbidity, however, the polarization in the short wave lengths exceeds that in the long, but where, through diffraction, little or no blue can originate, as in the neighborhood of the sun and in a damp layer, the excess is with the long wave part of the spectrum.—*M. A. G.*

RELATION BETWEEN THE ABSORPTION OF SOLAR RADIATION BY THE ATMOSPHERE AND THE POLARIZATION OF DIFFUSE SKY LIGHT.[7]

By A. BOUTARIC.

[Reprinted from *Science Abstracts*, Sect. A, Dec. 1920, § 1539.]

Finds that corresponding to an increase in the absorption of solar radiation by the atmosphere there is a corresponding decrease in the proportion of diffuse skylight polarized. The result is based on observations made at Montpellier on cloudless days, using the compensation pyrheliometer of K. Ångström and a Cornu polarimeter. Observations of humidity at the surface were also made on the same days. The portion of the sky chosen for the polarimetric observations was that 90° from the sun in the same vertical circle, this being the region of maximum polarization. The result was verified for observations (1) on the same day, comparing observations at time symmetrically placed with respect to noon; (2) on days close together, comparing observations at the same hour of the day; (3) on days belonging to different months, comparing observations at times corresponding to an equal thickness of atmosphere traversed by the solar radiation; (4) for corresponding days of different years. If on two occasions the conditions as to humidity are very different there may be an apparent exception, since this affects the observed intensity of radiation, but not the polarization. Further, in (3) a small correction is necessary for the effect on the intensity of radiation of the varying distance of the earth from the sun. It is suggested that there is a relation appropriate to a given station and possibly the same for all stations of the same altitude, of the form $I=f(d, t, P, f)$, where I is the intensity of solar radiation received at the earth's surface, d the distance of the sun from the earth, t the thickness of atmosphere traversed by the solar radiation, P the polarization, and f the vapor pressure in the air. t and P are of greater importance than d and f. In a further part the relation between absorption of direct and polarization of scattered radiation is studied as a laboratory experiment.—*M. A. G.*

[1] *Quarterly Journal, Royal Met. Socy*, various papers, 1889-1893 and *Proc. Royal Society*, vols. 48 and 50.
[2] *Annals*, Harvard College Obsy., vol. XL, Pt. IV, 1896.
[3] MONTHLY WEATHER REVIEW, February, 1900.
[4] Sachs. Akad. Wiss. Abhandl., Math. Phys. Klasse., 1918, 35:219.
[5] Soc. Spettros. Ital., Mem. 8, July-August, 1920, pp. 62-79.
[6] Ann. d. Physik, June 8, 1920, 62:283-292.
[7] Jour. de Physique, July, 1920, v. 9, pp. 239-256.

ON THE VARIATION OF NOCTURNAL RADIATION DURING STILL, CLEAR NIGHTS.

By A. BOUTARIC.

[Abstracted from *Comptes Rendus*, Paris Acad., Dec. 6, 1920, pp. 1165-1167.]

Contrary to conclusions made by Lo Surdo and Exner, at Naples and on the Sonnblick, respectively, the author found at Montpellier in 1913–14, and more recently at the Pic du Midi, that radiation on still, clear nights reaches a maximum shortly after sunset and then decreases slowly until sunrise. This phenomenon probably is to be attributed to the nocturnal march of temperature and vapor pressure, the first decreasing steadily through the night and thus tending to diminish the radiation, the second also decreasing and consequently tending to increase the radiation. There is another factor, namely, the nocturnal increase of temperature in the air a short distance above the ground, which increases the radiation from the atmosphere and decreases the effective radiation of a body exposed to the free air. The author urges further observations at numerous places in order to acquire more data on this temperature inversion. The formula which the author proposed in an earlier work [1] seems to be sufficiently accurate to render comparable the observations made by himself at Montpellier and the Pic du Midi, by Ångström at Bassour, and by Kimball at Washington. —*C. L. M.*

APPLICATION OF HEAT RADIATION MEASUREMENTS TO THE PROBLEMS OF THE EVAPORATION FROM LAKES AND THE HEAT CONVECTION AT THEIR SURFACES.

ANDERS ÅNGSTRÖM.

[Abstracted from *Geografiska Annaler* 1920, H. 3.]

After calling attention to the well-known difficulties of measuring evaporation from surfaces or pans, and the further difficulty of determining the actual evaporation from broad lakes or water surfaces, the author points out the possibility of determining the evaporation from natural water surfaces from a heat balance equation, the energy of evaporation being derived from the excess of heat received over heat lost through processes other than evaporation.

A literal equation is formulated, including terms for the various items of heat exchange from water surfaces through radiation, convection, diffusion, and conduction, as well as allowing for gain or loss of heat through storage in the water body in a given time-interval.

Some of the data necessary for determination of the constants in the various terms of this formula are available and are presented in some interesting and valuable tables showing, for example, the relative radiation received for different percentages of cloudiness and the relation of outgoing radiation to temperature and humidity. Using special observations taken for the Swedish Lake Vassijure, the author attempts to calculate the heat balance for specified time-intervals, when there was no gain or loss of heat storage, and the resulting evaporation. The data are meager, but the results are of the right order as compared with measured evaporation from the lake surface for the same interval. Comparison is also made with the evaporation calculated by Stelling's formula. The author concludes that Stelling's formula does not apply to condensation, and that condensation rarely or never occurs on open sea surfaces under natural conditions.

The second portion of the paper is devoted to a study of the possibility of determining convective heat exchange between air and water surfaces. The lines of observation necessary for the solution of this problem are pointed out, but data for numerical calculations are at present unavailable.—*R. E. Horton.*

[1] *Thèse*, Paris, 1918, p. 135. For paper giving in greater detail the formula, see *Comptes Rendus*, May 17, 1920, pp. 1195-1196; or an abstract in *Science Abstracts*, Nov. 1920, § 1375.

TWENTY-FOUR HOUR BAROMETER OSCILLATION IN RELATION TO SURFACE FEATURES.[2]

By J. VON HANN.

[Reprinted from *Science Abstracts*, December, 1920, §1240.]

Deals with the geographical distribution of the amplitude and phase of the 24-hour barometer oscillation and the effect on it of local conditions. From observations on ships and small ocean islands, the universal 24-hour oscillation is found to be given at the equator by 0.3 sin $(0°+x)$, the amplitude being in mm., thus having 6 a. m. maximum and a 6 p. m. minimum and differing in phase, as theory demands, by about 180° from the 24-hour temperature wave in the higher layers of the atmosphere. Beyond latitude 40° this universal oscillation becomes inappreciable or masked by that engendered by local surface features and differences of surface heating. This latter is studied by grouping coast and inland stations separately. Latitude is found to exert little influence on the phase, which in nearly all cases gives a night maximum between 6 p. m. and 6 a. m., but the amplitude tends to decrease with increasing latitude, though not regularly. The amplitude is, in general, greater inland than on the coast, the average values being in low latitudes about 0.8 mm. and 0.6 mm., respectively. Stations on mountain slopes and summits are also considered, some of the greatest amplitudes being found here. Finally, some outstanding types of daily-pressure curves are considered and their peculiarities traced to the 24-hour term and explained in the light of the results of the present paper.—*M. A. G.*

THE RELATIONSHIP BETWEEN PRESSURE AND TEMPERATURE AT THE SAME LEVEL IN THE FREE ATMOSPHERE.

By E. H. CHAPMAN.

(Abstracted from *Proceedings, Royal Society of London*, Dec. 3, 1920, 98A : 235-248.)

A correlation coefficient is always lowered in the numerical sense by errors of observation; consequently, after a careful investigation of the probable errors of measurement of temperature and pressure in the upper air, the author has corrected Dines' table of correlation coefficients between pressure and temperature at the same level in the free air [3] and obtains the following table of true correlation coefficients between those quantities:

Height in kilometers.	2	3	4	5	6	7	8	9	10
Jan.-Mar.	0.935	0.885	0.946	0.931	0.916	0.953	1.000	0.903	0.400
Apr.-June	0.559	0.900	1.000	0.992	1.006	0.957	0.891	0.491	0.216
July-Sept.	0.638	0.817	0.848	0.903	0.913	0.957	0.957	0.959	0.464
Oct.-Dec.	0.866	0.862	0.913	0.953	0.935	0.931	0.986	0.870	0.328

The direct proportionality at .8 km. for the first trimester and at 4 and 6 km. for the second trimester is very striking; and it would be profitable to consider what it is that spoils this relation in the other cases.—*E. W. W.*

[2] Akad. Wiss., Vienna, vol. 128, 2a, 1919, pp. 379-506.

[3] W. H. Dines: Characteristics of the Free Atmosphere. *M. O. Geophys.* Mem., No. 13, London, 1919. *Cf.* MONTHLY WEATHER REVIEW, 1919, 47: 644-647, and Computer's Handbook, Sec. V, No. 3, Sec. II, Subsections III-IV.

THE RELATION OF SOIL INSECTS TO CLIMATIC CONDITIONS.[1]

The soil responds directly to the meteorological conditions of the air, chief among which are pressure, humidity, and temperature. If those conditions favor the growth of plant life, they are also beneficial to that of the animal organisms which dwell all or a part of the time in the soil. Mr. Cameron states that "according as all climatic conditions allow, entomologists may rather accurately prophesy what genera and sometimes species of insects are likely to exact toll on the cultivated crops of any one district." He further says that a series of favorable weather occurrences, which the agriculturist may have considered quite unimportant, may cause a rapid increase of insect species. Unfavorable conditions may destroy the insects while in the soil, or retard their metamorphoses, though some species may adapt themselves to conditions which were at first unfavorable, especially if the environmental changes be slow. "As a physical index of the varied conditions which control an organism, the evaporating power of the air is supreme to any other." The relation of temperature to growth varies with the type of insect and with the phase of its existence in the soil. Thus humidity and temperature, together with the character of the soil, whether light or heavy, porous or compact, are determining factors. The writer emphasizes the necessity of intensive studies of the correlation between climatic conditions and insect life during hibernation for the purpose of forecasting more accurately the appearance of species which are economically friendly or disastrous to agriculture in the coming season.—*W. E. H.*

WEATHER AND THE OPENING OF COCOONS.

[Reprinted from *Scientific American Monthly*, New York, January, 1921, p. 15.]

The well-known Swiss scientist, M. A. Pictet, has made an extended series of experiments on the effect of the weather upon the opening of cocoons of moths and butterflies. The data discovered and published by him are most interesting and obviously of great significance in agriculture, since hundreds of thousands of the farmer's worst enemies spend a portion of their lives in the cocoon phase. It was found that in most varieties of insects, the emergence of the pupa from the cocoon coincides with the fall of barometer, and that a relative increase of the internal pressure within the cocoon is a necessary factor in the escape of the insect from its prison. When there is an augmentation of the atmospheric pressure during the entire time of this dormant stage of the pupa, or even during the latter half of this period alone, the duration of the dormant stage may be extended from 10 to 20 per cent. Furthermore, when the emergence of the insect is too long retarded, the pupa perishes while still in the cocoon.

A fall of a single millimeter of the mercury in the barometer tube was enough to cause the opening of the sufficiently mature cocoons, while, on the other hand, an increase in the atmospheric pressure was sufficient to postpone the coming forth of such insects for as much as two, three, or even four days until the barometer fell once more.

[1] "The Relation of Soil Insects to Climatic Conditions," by Alfred C. Cameron, M. A. D. Sc. From *The Agricultural Gazette of Canada*, vol. 4, No. 8, August, 1917.

OPEN ROADS ALL WINTER—DEFINITE SNOW REMOVAL PROGRAM IN NORTHERN AND EASTERN STATES.

By M. R. REYNOLDS.

[Excerpts reprinted from *Scientific American*, Feb. 5, 1921, p. 104, 117, 118.]

"* * * Modern highway transportation can not be carried on at convenience and treated with indifference. Railroads do not abandon their shippers when snow drifts block transportation, although it would often be more profitable to stop train service until the rails are cleared by natural agencies. * * *

"Heavy expenditures of money are necessary to keep the main trunk roads open * * * but in sections where the work has been carried on in former winters, its value has been so apparent that [under the general guidance of the Bureau of Public Roads of the United States Department of Agriculture] a concerted effort is being made this winter to keep open the main highways in all the States north of the Potomac and east of the Mississippi open to motor transportation.

* * * * *

"In the past, Pennsylvania has been the leader in snow removal. This winter it is doing more than ever has been attempted in the State before. Seventy-five additional trucks, with snow-plows and correlated mechanical facilities and snow-removal organizations, have been added to its equipment.

"The snow removal problem in Pennsylvania is difficult because of its many mountains and heavy snowfall. By removal of weeds, brush, and obstructions along the roadside in the fall, and by the liberal use of snow fences, the highway commissioners of that State, however, have found it possible to control drifting in such manner that heavy trucks can keep the roads clear with a minimum of assistance in the way of handwork.

"The Pennsylvania Highway Commission also makes use of the Weather Bureau * * * in combating the snow. The Weather Bureau informs the highway department in advance of the approach of storms and this information is sent at once to the field engineers who, with knowledge of the intensity of the coming storm and its probable duration, are more prepared to cope with it than they would be if it came unannounced. As getting on to the job in time and keeping on it until the storm is over are two of the most important factors in fighting a heavy snowfall, this advance information is of utmost importance in all States with a snow removal program.[2] Another admirable detail in the Pennsylvania winter program is the system of daily reports to the public on the condition of the principal highways. These are given both directly and through the Weather Bureau's daily bulletins."

* * * * *

"It is impossible to estimate what it will cost to keep different highways open for any winter. During the winter of 1919–20, which was the most severe in years in this section of the country [Pennsylvania], the cost ranged from $75 to $350 per mile, while during the year of 1918–19, the cost ranged from $10 to $30 per mile the entire winter."[3]

[2] Further detailed reports are given out by the Weather Bureau during the progress of the storm, and at its close the depth of snow that fell is given for the different sections.—EDITOR.

[3] This quotation is the concluding paragraph of an article on "Snow removal and drift prevention on highways," by G. H. Bil, Assistant Commissioner Pennsylvania Highway Department, Harrisburg Engineering News-Record, Feb. 3, 1921, 86:230-232, 4 photos.

WISCONSIN BEGINS SNOW SURVEY.

[Reprinted from Engineering News-Record, New York, Jan. 27, 1921, p. 181.]

On selected main highways in Wisconsin records are being kept this winter of the character and extent of snow movement by the wind; of drift formation, location, and magnitude, and all similar facts in connection with the accumulation of snow on these roads. Reports will be made on simple forms which, in addition to the snow data, call for suggestions as to means of prevention of drifts by windbreaks, fences, hedges, etc. It is believed that with such records plans may be formulated for barriers and other drift preventives which will materially reduce obstruction of highways. While the surveys are being conducted by country highway commissions, the routes surveyed are selected by the State Highway Commission, J. T. Donaghey, maintenance engineer.

ZONAL VARIATION OF THE YEARLY MARCH OF AIR TEMPERATURE.[1]

By F. K. VON MARILAUN.

[Reprinted from Science Abstracts, Dec., 1920, § 1239.]

The mean monthly temperature of zones each comprising 10° of latitude, as given by Hopfner (Petermann's geogr. Mitt. 52, 1906), are analyzed by obtaining the first three terms of Bessel's formula, this number giving sufficient approximation. Combining these terms, the times of maximum and minimum temperature for each zone are tabulated, together with the percentage of sea cover in each zone, thus bringing into prominence the tendency for greater lag with greater sea cover. The increase of yearly range of temperature with increased land cover is similarly exhibited and the relation is approximately linear if the range be divided by the latitude.

In the second paper the assumption often made that with a water hemisphere the zonal temperature decreases as $\cos\phi$, and with a land hemisphere as $\cos^2\phi$ is tested for such zonal temperatures partly empirical, partly theoretical, given by various authors. This rate of decrease is not found in any case. For a water hemisphere a good fit is obtained by using the expression $\cos^m\phi$, m being a function of ϕ, not the same for all the authors. The form of m is, however, a–$b\cos\phi$ in three out of the seven cases examined, a being near 2 and b near 1. This indicates a decrease proportional to $\cos\phi$ at the equator and to $\cos^2\phi$ at the pole. For a land hemisphere the expression $\cos^m\phi$ is also found suitable, but only with three authors out of five does m indicate a greater rate of decrease than with a water hemisphere.—*M. A. G.*

[1] Akad. Wiss., Vienna, vol. 128, 2a, 1919, pp. 145–174.

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SPECIAL OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING JANUARY, 1921.

By HERBERT H. KIMBALL, Meteorologist.

[Solar Radiation Investigations Section, Washington, Feb. 28, 1921.]

For a description of instruments and exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, **48:** 225.

From Table 1 it is seen that the solar radiation intensities measured averaged slightly above the normal for January at all the stations. At Washington, D. C. a noon intensity of 1.43 gram-calories per minute per square centimeter, measured on the 18th and again on the 26th is the highest intensity ever measured at Washington in January.

Table 2 shows a deficiency in the radiation received from the sun and sky at Madison and Lincoln, except during the second week, the deficiency being especially marked during the third and fourth weeks. This deficiency is to be attributed to the cloudiness. The table shows about the normal amount of insolation at Washington.

Sky-light polarization measurements obtained on four days at Madison when the ground was free from snow give a mean of 72 per cent and a maximum of 76 per cent on the 23d. There was practically no snow on the ground during the month at Washington, and sky polarization measurements obtained on four days give a mean of 60 per cent, with a maximum of 65 per cent on the 4th. These are slightly above the January averages at both stations.

TABLE 1.—*Solar radiation intensities during January, 1921.*

[Gram-calories per minute per square centimeter of normal surface.]

WASHINGTON, D. C.

Date.	Sun's zenith distance.										
	8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th meridian time.	Air mass.									Local mean solar time.
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
Jan. 4	4.57	0.76	0.87	0.98	1.19	1.39		1.01	0.87	0.75	5.56
5	6.50							1.01			5.36
17	4.80	0.65	0.76	0.90	1.24						1.52

* Extrapolated.

TABLE 1.—*Solar radiation intensities during January, 1921*—Contd.

WASHINGTON, D. C.—Continued.

Date.	Sun's zenith distance.										
	8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th meridian time.	Air mass.									Local mean solar time.
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
Jan. 18	3.73	1.01	1.13		1.43	1.61	1.42			1.14	1.12
21	3.81		0.69	0.90							4.95
23	7.04				1.26						4.57
24	2.49	0.77					1.09	0.81	0.58		2.62
25	1.32	0.99	1.09	1.21	1.37	1.54					1.24
26	1.12			1.26	1.40		1.38	1.13			1.52
27	1.60							1.05			1.24
28	1.60	0.88	0.97	1.12	1.11						1.96
Means		**0.84**	**0.92**	**1.06**	**1.29**		**1.30**	**1.01**	**(0.72)**	**(0.94)**	
Departures		**+0.07**	**+0.04**	**+0.04**	**+0.06**		**+0.06**	**−0.02**	**−0.16**	**+0.15**	

MADISON, WIS.

Jan. 8	2.74	0.92	1.09	1.29				1.31			3.62
12	0.86	1.11	1.22	1.34		1.60		1.32			1.07
17	0.86		1.13								1.32
23	3.30		1.14		1.40	1.56					3.00
24	2.26		1.03								2.87
26	2.49							1.06	1.01		3.30
Means		**(1.02)**	**1.12**	**(1.32)**	**(1.40)**			**1.23**	**(1.01)**		
Departures		**+0.08**	**+0.03**	**+0.06**	**+0.05**			**−0.01**	**−0.12**		

LINCOLN, NEBR.

Jan. 11	1.96				1.51						3.30
12	1.24	1.03	1.20	1.31				1.25	1.15		1.78
14	2.26			1.26							3.81
21	4.17			1.09							5.56
Means		**(1.03)**	**(1.20)**	**1.22**	**(1.51)**			**(1.25)**	**(1.15)**		
Departures		**+0.07**	**+0.14**	**+0.04**	**+0.14**			**+0.04**	**+0.07**		

SANTA FE, N. MEX.

Jan. 8	1.68				1.54						1.32
14	1.68			1.43	1.52		1.53	1.38	1.29	1.19	2.00
15	2.16						1.48	1.32			3.15
24	1.88			1.44	1.54			1.35	1.18	1.10	2.74
25	2.06			1.41	1.57		1.45				2.62
28	3.81			1.21							4.37
29	3.99						1.51				2.87
Means				**1.37**	**1.54**		**1.49**	**1.35**	**(1.24)**	**(1.14)**	
Departures				**−0.01**	**+0.03**		**+0.01**	**+0.01**	**+0.02**	**−0.01**	

* Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning—	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Jan. 1....	154	115	173	− 6	−28	−13	− 44	−198	− 91
8....	65	159	210	−103	+ 7	+13	−763	−150	± 0
15....	228	137	161	+ 52	−31	−49	−398	−368	−344
22....	235	150	133	+ 73	−37	−92	+114	−630	−990

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE, DECEMBER, 1920.

By C. G. ABBOT.

In continuation of the preceding publications, I give in the following table the results obtained at Montezuma, near Calama, Chile, in December, 1920, for the solar constant of radiation. The reader is referred to this REVIEW for February, August, and September, 1919, for statements of the arrangement and meaning of the table.

Mr. L. H. Abbot succeeded Mr. A. F. Moore as director of this station on December 22.

Date.	Solar constant.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity. ρ/ρSC.	Humidity. V. P.	Humidity. Relative humidity.	Remarks.
1920. A. M.	*cal.*					*c.m.*	*Per ct.*	
Dec. 3	1.945	$M_{1.5}$	S	0.858	0.589	0.28	18	Clouds in east preventing earlier observations.
	1.943	$M_{1.46}$						
	1.944	W. M.						
4	1.964	M_2	S	.859	.516	.22	17	Clouds prevented earlier observations—in west and low in east.
	1.968	$M_{1.5}$						
	1.966	W. M.						
5	1.936	E_0	VG+	.874	.482	.44	41	Clouds low in east.
	1.974	M_3						
	1.955	$M_{2.5}$						
	1.956	M_2						
	1.955	W. M.						
6	1.959	M_3	S−	.872	.618	.23	21	
	1.963	$M_{2.5}$						
	1.950	M_2						
	1.959	W. M.						
7	1.953	M_3	S	.877	.550	.23	22	
	1.951	$M_{2.5}$						
	1.950	M_2						
	1.954	W. M.						
8	1.949	E_0	VG	.875	.497	.38	40	Some cirri low in east.
	1.969	M_3						
	1.973	$M_{2.5}$						
1920. A. M. Dec. 8	1.945	$M_{1.84}$						
	1.959	W. M.						
P. M. 10	1.964	$M_{1.09}$	S−	.865	.663	.49	27	Clouds forming in various directions. Clear around sun.
	1.972	$M_{1.05}$						
	1.962	$M_{1.04}$						
	1.965	W. M.						
A. M. 11	1.984	E_0	E−	.866	.501	.36	42	
	1.961	M_3						
	1.976	$M_{2.5}$						
	1.979	M_2						
	1.977	W. M.						
12	1.956	$M_{2.5}$	S	.875	.634	.26	27	
	1.960	M_2						
	1.959	W. M.						
13	1.945	M_3	S−	.877	.652	.18	18	Low cirri in east.
	1.954	$M_{2.5}$						
	1.973	M_2						
	1.957	W. M.						
14	1.948	M_3	S	.875	.648	.18	16	Cirri low in east.
	1.946	$M_{2.5}$						
	1.945	M_2						
	1.946	W. M.						
15	1.971	E_0	VG+	.871	.654	.21	21	
	1.945	M_3						
	1.954	$M_{2.5}$						
	1.942	M_2						
	1.949	W. M.						
16	1.954	M_2	S	.872	.706	.30	22	
	1.952	$M_{1.5}$						
	1.953	W. M.						
17	1.960	M_2	S	.873	.703	.34	26	
	1.964	$M_{1.5}$						
	1.962	W. M.						
18	1.948	M_2	S	.864	.626	.34	24	Some cirri in north.
	1.962	$M_{1.5}$						
	1.954	W. M.						
19	1.950	M_2	S−	.875	.740	.26	18	Cirri low in north and east.
	1.968	$M_{1.5}$						
	1.959	W. M.						
20	1.941	M_3	S	.871	.648	.18	18	Do.
	1.959	$M_{2.5}$						
	1.950	W. M.						
P. M. 22	1.962	$M_{1.12}$	S−	.864	.656	.28	13	Cirri in most of sky preventing earlier observations.
25	1.935	$M_{1.98}$	S−	.856	.503	.38	15	Scattered cirri, especially in east.
	1.953	$M_{1.20}$						
	1.944	W. M.						
A. M. 30	1.955	$M_{1.80}$	S	.853	.512	.47	40	Small patch of cirri near sun prevented earlier observations.
	1.954	$M_{1.70}$						
	1.954	W. M.						
31	1.959	M_3	S	.856	.415	.54	62	Cirri low in east and north.
	1.972	$M_{2.5}$						
	1.966	W. M.						

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. Young.

The average pressure for the month of January was considerably above the normal at land stations in the Azores; slightly above in the West Indies and on the shores of the Gulf of Mexico; nearly normal along the American coast from Nova Scotia to Florida, and coniderably below at St. Johns, Newfoundland, and Lerwick, Scotland.

The number of days on which winds of gale force were reported, was as a whole, not far from the normal over the entire ocean, and the month was characterized by a succession of gales over different portions of the steamer lanes, with infrequent intervals of comparatively moderate weather.

There were few fog reports received from vessels, although it was recorded frequently by land stations in the British Isles.

On the 2d, there was a disturbance central near mid-ocean, and moderate gales covered a large area, which extended as far south as the 30th parallel. From the 3d to the 9th there was apparently an area of low pressure in the northeastern section of the ocean, although it was impossible to determine its center and extent accurately on account of lack of observations. A number of vessels in widely scattered localities experienced heavy weather during this period, as shown by the following storm logs:

British S. S. *Vasconia:*

Gale began on the 2d. Lowest barometer 29.43 inches at 2 a. m. on the 3d; position, latitude 50° 41′ N., longitude, 20° 33′ W. End of gale on the 3d. Highest force of wind 10; shifts near time of lowest barometer S.-SW.

American S. S. *West Chenow:*

Gale began on the 2d. Lowest barometer 29.22 inches at 2 p.m. on the 2d; position, latitude 50° 36′ N., longitude 23° 06′ W. End of gale on the 5th. Highest force of wind 9; shifts S.-SSW.-NW.

British S. S. *Cairndhu:*

Gale began on the 6th. Lowest barometer 29.22 inches at 6 p. m. on the 6th; position, latitude 57° N., longitude 25° W. End of gale at midnight on the 7th. Highest force of wind 10; shifts NW.-W.

British S. S. *Hartfield:*

Gale began at 7 a. m. on the 6th. Lowest barometer 29.66 inches at 5 a. m. on the 7th; position, latitude 35° 26′ N. longitude 56° 50′ W. End of gale on the 7th. Highest force of wind 10; shifts SW.-NW.

Japanese S. S. *Tomiura Maru:*

Gale began on the 7th. Lowest barometer 29.91 inches at 6 a. m. on the 8th; position, latitude 33° 10′ N., longitude 42° 40′ W. End of gale on the 8th. Highest force of wind 10; shifts SSE.-S.-W.-NW.

The observer on the British S. S. *West Hampton* states, that on the evening of the 6th Bell of Portland light was visible at 35 miles, and flare of Ushant was sighted at 63 miles.

Charts IX, X, and XI show the conditions on January 10, 11, and 12, respectively, during which period exceptionally severe weather was experienced over a large portion of the ocean. Storm logs follow:

British S. S. *Hartfield:*

Gale began on the 9th. Lowest barometer 29.75 inches at 7 a. m. on the 11th; position, latitude 36° 10′ N., longitude 68° 06′ W. End of gale at midnight on the 11th. Highest force of wind 9; shifts S.-SW.-NW.

British S. S. *Saturnia:*

Gale began on the 8th. Lowest barometer 29.60 inches at noon on the 8th, while in the Irish Channel. End of gale on the 11th. Highest force of wind 10; shifts SW.-W.

British S. S. *Cairndhu:*

Gale began on the 10th. Lowest barometer 29.34 inches at 4 p. m. on the 10th; position, latitude 50° 20′ N., longitude 45° 02′ W. End of gale on the 12th. Highest force of wind 12; shifts NNW.-NW.

American S. S. *West Alcoz:*

Gale began on the 9th. Lowest barometer 29.67 inches at 10 a. m. on the 10th; position, latitude 49° N., longitude 15° W. End of gale at 6 p. m. on the 10th. Highest force of wind 10; shifts SW.-WNW.

Belgian S. S. *Eglantier:*

Gale began on the 11th. Lowest barometer 29.80 inches at 4 a. m. on the 11th; position, latitude 35° 45′ N., longitude 67° 20′ W. End of gale on the 11th. Highest force of wind 11; steady from SW.

Dutch S. S. (tanker) *Rotterdam:*

Gale began on the 12th. Lowest barometer 28.79 inches at 5 a. m. on the 13th; position, latitude 47° 59′ N., longitude 35° 40′ W. End of gale on the 13th. Highest force of wind 11; shifts to SSW.-W.-WNW.

On the 13th a number of vessels in the vicinity of the Bermudas encountered northerly gales, and there was also a disturbance central about 400 miles east of St. Johns, N. F. Storm logs follow:

Japanese S. S. *Tomiura Maru:*

Gales began on the 12th. Lowest barometer 29.85 inches at 6 a. m. on the 13th; position, latitude 34° 24′ N., longitude 60° 52′ W. End of gale on the 13th. Highest force of wind 10; shifts of wind W.-WNW.-N.

British S. S. *Zeeland:*

Gale began on the 13th. Lowest barometer 28.80 inches at 11 p. m. on the 13th; position, latitude 44° 05′ N., longitude 40° 34′ W. End of gale at 8 a. m. on the 15th. Highest force of wind 12; shifts SW.-NW.

On the 14th there was an extensive storm area over the steamer lanes, between the 25th and 50th meridians. On the same day vessels in the western part of the Gulf of Mexico encountered a "norther" of a velocity of from 40 to 55 miles an hour. On the 15th vessels in the region between Charleston and the 75th meridian experienced severe gales, as shown by the daily journal of the American S. S. *Comus:*

7 a. m., January 15: Position, latitude 30° N., longitude 79° 35′ W.; westerly gale with rain squalls, moderate sea and cloudy sky. 7 p. m.: Position, latitude 32° 20′ N., longitude 77° 45′ W.; moderate westerly gale, occasional rain squalls.

From the 16th to the 19th there was a severe disturbance between the 25th meridian and the coast of Scotland, as shown by the following storm log from the Norwegian S. S. *Ranenfjord:*

Gale began at 7 a. m. on the 16th. Lowest barometer 28.89 inches at 3 p. m. on the 17th; position, latitude 58° N., longitude 17° W. End of gale on the 20th. Highest force of wind 12; shifts not given.

On the 17th there were moderate westerly and southwesterly gales along the American coast between Nantucket and Hatteras. From the 21st to the 24th southerly gales prevailed over the middle and eastern sections of the steamer lanes. The storm log from the British S. S. *Maine* follows:

Gale began on the 21st. Lowest barometer 29.16 inches at 1 p. m. on the 23d; position, latitude 45° 34′ N., longitude 35° 36′ W. End of gale on the 24th. Highest force of wind 11; shifts SSE.-W.

On the 24th a low was central near Sydney, Nova Scotia, and the storm area extended as far south as the 35th meridian. Storm log from the American S. S. *The Angeles* follows:

Gale began on the 23d. Lowest barometer 29.80 inches on the 24th; position, latitude 35° 20′ W., longitude 62° 40′ W. End of gale on the 26th. Highest force of wind 10; shifts WSW.-WNW.

Charts XII and XIII show the conditions for January 25 and 26, respectively, and on the latter date heavy weather was the rule over the greater part of the ocean between the 35th and 50th parallels and the 30th and 65th meridians.

On the 28th moderate northeasterly gales were reported from a limited area in the vicinity of Hatteras, and on the 29th westerly winds of gale force were encountered by vessels near latitude 47°, longitude 33°. On both of these dates, with the exceptions stated, moderate weather prevailed. The conditions were similar on the 30th and 31st except for a small area between the 15th meridian and the French coast where a few vessels reported northwesterly gales. The storm log from the Danish S. S. *Pennsylvania* follows:

Gale began on the 30th. Lowest barometer 29.42 inches at 4 p. m. on the 30th; position, latitude 46° 25′ N., longitude 13° 30′ W. End of gale on the 31st. Highest force of wind 9; shifts WNW.-NW.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

The abnormally low pressure which prevailed at Midway Island during the last decade of December gave way to high pressure at the beginning of January and this continued throughout the month. During the middle decade readings above 30.40 inches were recorded on several days. A similar change in pressure occurred at Dutch Harbor. At Honolulu pressure was somewhat above normal during the first half of the month and slightly below, on an average, during the latter half.

As would be inferred from the general change in pressure distribution the weather of the month was not so persistently stormy as was that of December, especially along the northern steamer route, although gales prevailed there on several occasions. On the other hand, unusual northeast gales occurred in the lower latitudes, especially during the period of highest pressure at Midway Island, or from the 10th to 17th, inclusive.

The opening days of the month brought an abatement of the severe gales which had swept the western part of the North Pacific during the last decade of December, reference to which was made in the review of the weather for that month. Relative quiet then prevailed until about the 8th, when reports indicate the renewal of storm conditions. Thereafter for several days vessels on the northern steamer routes experienced moderate to strong gales. During the 8th and 9th these occurred over the eastern portion of the ocean and were occasioned by a depression over southwestern Alaska. During the same dates and continuing until the 12th they were due to a series of depressions which advanced over Japan and the Kurile Islands. Following is the storm log of the Japanese S. S. *Sumatra Maru*, Capt. J. Nishida, Yokohama (January 5) for San Francisco, covering the 11th and 12th:

Gale began on the 11th; lowest barometer, 29.47 inches at 8 a. m. of the 12th in latitude 43° 59′ N., longitude 161° 17′ E.; highest force of wind, 11, from SSE.; shifts of wind, SSE.-S.-SW.-WSW.

According to Observer K. Tsujimura, the *Sumatra Maru* also had heavy weather on the 8th and 9th, 15th and 16th, and 24th.

The northeast gales in the lower latitudes which accompanied the high pressure in mid-ocean, already referred to, were experienced by several vessels which furnish meteorological reports to the Weather Bureau. A special report has also been furnished by Capt. Albert Wilson of the American S. S. *West Neris*, as follows:

The S. S. *West Neris*, en route on the circle from Van Diemen Strait to Honolulu, encountered in latitude 25° 45′ N., latitude 179° 30′ W., a violent gale with heavy squalls and a big sea, beginning from NE., true, at 10 p. m. January 12, shifting to ENE. the following day and ending at E. on January 17, 2 a. m. (five consecutive days) in latitude 22° 20′ N., longitude 169° 30′ W.

The *West Neris* during the above-mentioned dates was driven 110 miles south of her position on the circle, being unable to bear up to her course, the vessel being light.

The barometer on the *West Neris* for the five days commencing with the 12th read as follows: 30.32, 30.36, 30.38, 30.32, 30.24 inches, at Greenwich mean noon.

The American S. S. *Columbia*, Capt. Thomas Blair, Yokohama for Honolulu, had a similar experience. Mr. Elb, the observer, states that the northeast gale which began on the 12th in longitude 177° 30′ E. was still raging when the vessel came under the lee of the Hawaiian Islands on the 18th.

The American S. S. *West Hika*, Capt. H. Paulsen, Manila for Honolulu, also encountered these gales. Mr. H. C. Olsen, third officer and observer, states that they were caused by exceptionally strong trades.

These northeast gales were not confined to midocean. During the period from the 19th to the 26th the Norwegian M. S. *Theodore Roosevelt*, Capt. Eric Thomle, Caleta Buena (Chili) for Honolulu, had continuous fresh to strong NE. gales when between latitude 8° N., longitude 128° W. and latitude 20° N., longitude 153° W. During the whole time the barometer was very steady at about 30.16 inches.

On the 15th and 16th the Dutch S. S. *Eibergen*, Capt. W. H. de Forge, Portland (Oreg.) for Panama, at about latitude 14° N., 96° W., experienced a northeast storm, force 11, with high to phenomenal sea.

It is interesting to note that just previous to the commencement of these northeast gales in the North Pacific there had been a period of strong westerly winds in portions of the South Pacific, as reported by the Dutch S. S. *Rotti*, Capt. J. P. Scholtes, Macassar for Newcastle (N. S. W.). Mr. Cj. Mulder, observer on the *Rotti*, states that from January 4, when in latitude 9° 24′ S., longitude 132° 14′ E., until entering Torres Strait, on the 9th, a very strong SW. monsoon was experienced, the force varying generally from 5 to 7 and reaching 8 during squalls.

On the 28th and 29th several vessels off the northwest coast of the United States were involved in the disturbance, which, on the 29th, occasioned the record-breaking winds on the mainland. A velocity of 132 miles an hour was recorded at the North Head (Wash.) station before the instruments were carried away. The extreme velocity was estimated by the observer at 150 miles an hour.

The American M. S. *Sierra*, Capt. Olaf A. Janson, Bellingham for Callao, was proceeding down the coast at the time and felt the full force of the gale. Observer John Behrsin has furnished the following report:

At 9 a. m. on the 29th the wind, which previously had died down to force 3, increased to force 5, SSE.; by noon it had increased to force 12 and changed to S. and a little later to WSW., when it started to lose its force. A high and choppy sea was running and the vessel was rolling, pitching, and shipping heavy seas. For a while it seemed that we would lose our deck load of lumber and this would have happened had the wind not moderated when it did. When the wind was at its highest force, between 11 a. m. and 12 noon, the water of the sea was driven in the air in sheets just like heavy rain driven by a strong wind. It was not raining at the time although it was cloudy.

The barometer on board the *Sierra* read as follows: 9 a. m., 29.52 inches; 10:20 a. m., 29.45 inches; 12:55 p. m., 29.22 inches; 3 p. m., 29.50 inches; 8 p. m., 29.70 inches; midnight, 29.75 inches.

At North Head, 150 miles north of the position of the *Sierra*, the barograph trace shows a sharp fall in pressure to a minimum of 28.90 inches shortly after 3:30 p. m., followed by an equally rapid rise. At Tatoosh Island, 150 miles north of North Head, a similar fluctuation of pressure occurred, a minimum of 28.78 inches being recorded at 7 p. m. The observed conditions point to the northward movement of a small secondary depression, of imperfect formation, at a speed of about 50 miles an hour.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

Atlantic Ocean.—On December 31, the International Mercantile Marine Co. announced a change in the trans-Atlantic steamship routes on account of ice recently reported in low latitudes. The alteration, which ordinarily takes place in February, was to become effective immediately.[1]

Iceland.—The mild winter has caused a failure of the usual local supply of ice needed for preserving herring. * * *—*The Pathfinder, Jan. 29, 1921.*

British Isles.—In all parts of the British Isles the abnormally mild weather which set in just before Christmas was continued nearly throughout the whole of January.

The general rainfall for the countries expressed as a percentage of the average were England and Wales, 146; Scotland, 168; Ireland, 119. * * *

In London (Camden Square) the mean temperature was 46° F., or 7.3° above the average. Only two days (15th and 16th) had a mean temperature below the January average, and five days had a mean above 50° F. Since 1858 only one December, no Januaries, no Februaries, and five Marches have had a higher mean temperature.[1]

Western Europe.—* * * Over a large part of western Europe mild, stormy, and unsettled weather with southwesterly winds, alternated with briefer spells of the finer, colder weather occurring in the rear of the depressions and their secondaries.[1]

Northern Europe.—In northern Europe the weather was, for the most part, cold, and severe frosts were experienced at some of the stations in Norway and Sweden.[1]

Italy.—In Italy and the central part of the Mediterranean fair weather prevailed, except in the middle of the month, when a depression in that region caused an unsettled period.[1]

India.—January 13.—Famine is officially declared to exist in one of the districts of India, while there is a food scarcity in many other districts as the result of lack of winter rains for the crops. * * * —*Washington Star, January 13, 1921.*

During the week ending January 22, * * * light to heavy rain was general in the northeastern and central parts of the country and parts of Madras. While this fall was of considerable benefit more rain is needed in the majority of the provinces.[1]

Hawaii.—Honolulu, January 17.—Storms which struck the Hawaiian Islands Saturday and yesterday (Jan. 15–16) expended greatest violence on the island of Kauai, according to advices received here to-night. * * *

One district of Honolulu County reported 20 inches of rain fell Saturday night and Sunday. * * *

The Oahu railroad services were disorganized by washouts. The highway system was blocked by many slides and washouts.—*Washington Star, January 18, 1921.*

Australia.—At the beginning of the month heavy general rain occurred in Victoria and fairly heavy falls in the Riverina district in New South Wales. Isolated rainfalls were experienced in northern New South Wales and in South Queensland. Beneficial rain fell throughout New Zealand during the month.[1]

[1] *The Meteorological Magazine*, February, 1921, pp. 23 and 28.

DETAILS OF THE WEATHER OF THE UNITED STATES.

CYCLONES AND ANTICYCLONES.

By W. P. DAY, Observer.

The majority of the LOWS passed along the northern border of the United States, making their first appearance over the North Pacific or Alberta with a few secondary developments over the southern plateau.

The number of HIGHS was slightly above the normal and they generally originated over the Pacific Ocean. However, the great HIGH of January 16–21 was of the Alberta type.

The table below gives the number of HIGHS and LOWS by types:

Lows.	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mountain.	Colorado.	Texas.	East Gulf.	South Atlantic.	Central.	Total.
January, 1921	5.0	4.0	1.0	......	3.0	......	1.0	......	......	14.0
Average number, 1892–1912	4.7	2.5	0.9	0.4	1.4	1.5	0.4	0.4	0.5	12.7

Highs.	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain region.	Hudson Bay.	Total.
January, 1921	2.0	4.0	3.0	3.0	1.0	13.0
Average number, 1892–1912	0.8	0.6	5.5	1.7	0.4	9.0

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Weather Bureau, Washington, Mar. 2, 1921.]

PRESSURE AND WINDS.

The distribution of atmospheric pressure during the month was materially different from that usual to midwinter, and illustrates how profoundly small variations may alter the normal courses of cyclones and anticyclones over particular regions. Continued low pressure in the far Northwest and generally over the western Canadian Provinces, was unfavorable for the southward movement of anticyclones into the western United States, and pressure higher than normal over the Central and Southeastern States resisted the usual southeastward trend of storms entering the country from the North Pacific regions. Although the month was unusually stormy over the far Northwest, few of the low-pressure areas crossed the mountains with material strength, and storms of wide extent or of considerable severity were notably absent over the districts from the Rocky Mountains eastward.

The high-pressure areas developed mainly in the plateau regions and drifted thence eastward or southeastward and thus maintained pressure above normal in all central and southern districts. The principal exception to this was during the latter part of the second decade, when a high area of wide extent entered the Missouri Valley from the Canadian Northwest and slowly moved

eastward along the northern border. Its influence was felt, however, over all districts from the Rocky Mountains eastward and some of the highest barometer readings ever observed were reported at a number of stations from the Great Lakes southeastward to the middle Atlantic coast.

The stormy conditions in the far Northwest continued throughout the month and near the close, one of the severest wind storms ever experienced in that part of the country swept the coast districts of Oregon and Washington, causing almost incalculable damage to the standing timber in portions of the most extensive and heavily forested area in the United States. A partial report on the extent of, and damage from, this storm appears in another portion of this REVIEW.

For the month as a whole, pressure was low over the Northwest and in the adjoining Canadian Provinces, and high over the remaining districts, particularly so in the more southern districts. In the absence of marked pressure variations, wind velocities were usually moderate and high winds were the exception, save in a few instances.

The principal sections with winds of 50 miles or more per hour, were along the North Atlantic coast on the 17th and 20th, in the region of the Great Lakes and to the westward on the 15th and 16th, and over the North Pacific coast on the 29th.

The frequent occurrences of high pressure over southern districts favored winds from southerly quadrants penetrating far to the northward of their usual limits, and their influence on the weather of the month is graphically shown on Chart IV of this REVIEW.

TEMPERATURE.

Mild weather prevailed during the early part of the month over all sections, except in the far Southwest, where moderately low temperatures were the rule. Shortly after the middle of the first decade considerably cooler weather overspread the East and Southeast but this was quickly followed by higher temperatures, while cooler weather overspread the Rocky Mountain section, with temperatures below zero in some localities. There was a general tendency to lower temperatures at the close of this decade, although they remained mostly near the seasonal average. After a few days of moderate temperatures, the coldest weather of the month overspread most sections east of the Great Plains, and killing frosts were reported in northern Florida and heavy frost to the central portion of the peninsula. During the third decade the temperatures were above the normal almost everywhere except in the Atlantic Coast States, along the northern border, and on the Pacific slope.

For the month as a whole, the temperature averaged above the normal in all districts, except locally in the far Southwest and along the immediate Pacific coast. The plus departures ranged from 4 to 9 degrees a day in nearly all Southern States, and also from the Ohio Valley and Lake region eastward. In the upper Mississippi Valley and the central and northern Great Plains the temperature averaged from 9 to 16 degrees a day above normal, while in the Rocky Mountain and plateau regions the averages ranged from 4 to 6 degrees above.

The month may be classed among the warmest of record for midwinter over many portions of the country, and at a few points, notably in the Missouri and upper Mississippi Valleys, it was the warmest in the past fifty years or more. No portion of the month was markedly warmer than other portions over large areas, and the maximum temperatures were observed on many different dates for the various sections. The lowest temperatures were confined largely to the middle decade and very generally during the early part. A minimum of $-40°$ F., the lowest observed, was reported from a point in Wyoming, and temperatures of $-30°$ F. or more were reported from several of the mountain States, also along the northern border and in the elevated portions of New York and New England.

PRECIPITATION.

Precipitation was of moderate frequency over most districts, and as a rule the falls were mainly light, except for fairly heavy rains over the southeastern States on the 9th and 10th; from the west Gulf States northeastward and eastward on the 13th to 15th; on the Pacific coast about the 17th and 18th; over the southern plains on the 23d and 24th; and again on the Pacific coast on the 29th and 30th.

For the month as a whole, precipitation was less than normal over large portions of the country and, save for small areas in the southern Appalachian region, the entire country from the Mississippi Valley eastward had far less than the normal for the month. In the vicinity of the Great Lakes the precipitation was decidedly scanty for a winter month, some stations reporting the monthly fall as being the least for January in a period of 50 years, due mainly to the small snowfall. In the southern Plains, the precipitation was generally greater than usual for January, and similar conditions prevailed in California and Oregon and over portions of the plateau.

SNOWFALL.

The early part of the month was remarkably free from stormy conditions usually expected in the midwinter period, and such snow as fell was largely local. However, toward the latter part of the first decade, some unusually heavy falls occurred in the mountain districts of Virginia and North Carolina. Some snow also fell over considerable areas in the western mountain districts and locally in New England. Throughout the second decade the snowfalls were mostly light, except in the vicinity of Lake Superior, where some heavy falls occurred. Deep snows fell during the early part of the third decade in portions of the mountain districts of California, and light falls were general in the other mountain sections as far east as the central portions of the plateau region and also in portions of the lake region, New England, the Ohio Valley, and the southern Appalachian region.

In portions of the Carolinas and Virginia the snowfall for the month appears to have been the heaviest of recent years, some localities receiving during the month over 30 inches. In the high mountains of the West there were material increases over important areas in the snow depth, particularly in the mountains of California, Oregon, and Washington, and portions of Idaho and Nevada. Compared with the same period last year, there was much less snow over all sections from the Rocky Mountains eastward, but in the mountains of the West there was generally more.

At the close of the month the amounts of snow stored in many of the western mountains were close to or above, the normal, and the outlook for a satisfactory supply of water next summer was good.

RELATIVE HUMIDITY.

In the southern portion of New England, the coastal portion of the central and western Gulf States, the cen-

tral and northern Great Plains, and the far Southwest, the relative humidity was as a rule above the seasonal average, while generally elsewhere there was relatively less moisture in the atmosphere than is usual for January, although in many instances excesses occurred. This was notably the case in portions of the central and upper Mississippi Valley and the Lake region, where despite the small amount of rainfall the relative humidity averaged above the normal.

SEVERE STORMS.

The most important storm of the month, in fact probably the only one causing material property damage on account of high winds, occurred over the immediate coast districts of Oregon and Washington on the afternoon of the 29th. This storm occurred in connection with a low pressure area that appears to have been approaching the northwest coast of Washington from the adjacent ocean.

At the morning observation of the 29th, pressure was low and falling, as indicated by the few reports received from that section, but the rate of fall did not suggest unusual conditions, as this is a region of great storm activity during the winter months and high winds are of frequent occurrence, particularly near the coast. The pressure continued to fall after the morning observation, and by early afternoon it was quite low along the entire coast from the mouth of the Columbia River northward to British Columbia.

At the North Head station located on the Washington side, at the mouth of the Columbia River, the lowest pressure was reached at about 3:30 p. m. Prior to about 3:20 p. m. the wind had not attained a velocity greater than 40 miles per hour, but within a few minutes, the wind suddenly increased greatly in force and by 3:32 p. m. had reached a velocity of 126 miles per hour based upon a five-minute record, with an extreme velocity for a single minute at the rate of 150 miles per hour.

A further description of the storm can best be expressed in the words of the Weather Bureau observer at that station, which are extracted from his official report.

At 8 a. m. on January 29, 1921, small craft warnings were displayed as ordered by the district forecaster. At 11:40 a. m., local time, a special observation was taken and sent to the district forecaster. At this observation the sea-level pressure was 29.43 inches. The two-hour pressure change was −0.16 inch. Wind east 24 miles per hour. The barometer continued to fall rapidly until about 2 p. m. when it seemed that the center of the LOW had been reached and fell very slowly. Near 2:30 p. m., as no orders had been received to change the warnings and the barometer had almost stopped falling, I concluded that the storm was similar to the one of January 16 and 17. We were in need of some supplies and the mail from Ilwaco. By using the car it requires about one hour to make the trip to the post office and return. At 2:40 p. m., Mrs. Hill and I left the office. After getting the mail from the post office and a few articles from the stores in Ilwaco we started for home, but the extreme low air pressure probably affected the motor of the machine and a short delay from this cause probably saved our lives.

The road from Ilwaco to North Head is through a heavy forest of spruce and hemlock timber for some distance. On the return trip shortly before reaching the heavy timber, the wind came with quite a heavy gust. We saw the top of a rotted tree break off and fall out of sight in the brush. About this time (near 3:20 p. m.) we were overtaken by a young man from the naval radio station at North Head who was driving a car. It is dangerous driving over this road under favorable conditions. We proceeded very slowly and with great care, passing over some large limbs that had fallen and through showers of spruce and hemlock twigs and small limbs blown from the trees. We soon came to a telephone pole across the roadway and brought our car to a stop, for a short distance beyond the pole an immense spruce tree lay across the road. We left the machines and started to run down the road toward a space in the forest where the timber was lighter. Just after leaving the car, I chanced to look up and saw a limb sailing through the air toward us; I caught Mrs. Hill by the hand and we ran; an instant later the limb, which was about 12 inches in diameter, crashed where we had stood. In three or four minutes we had climbed over two immense tree trunks and reached the place in which I thought was our only chance to escape serious injury or possibly death. The southeast wind roared through the forest, the falling trees crashed to the ground in every direction from where we stood. Many were broken off where their diameter was as much as 4 feet. A giant spruce fell across the roadway burying itself through the planks within 10 feet of where we stood. Tree tops broke off and sailed through the air, some of the trees fell with a crash, others toppled over slowly as their roots were torn from the earth. In a few minutes there were but two trees left standing that were dangerous to us and we watched every movement of their large trunks and comparatively small tops.

Between 3:45 p. m. and 3:50 p. m. the wind shifted to the south and the velocity decreased to probably 100 miles or it may have been as low as 90 miles per hour. Shortly after 3:50 p. m. we started toward North Head. We climbed over some of the fallen trunks, crawled under others, and pushed our way through tangled masses of tops that lined the roadway. We supposed that all the houses at North Head had been leveled and the wireless station demolished for we knew that the storm was the most severe that had occurred in the vicinity of the mouth of the Columbia within the last 200 years. Mr. Seui, the young man from the radio station who was with us, hastened through the obstructions, and Mrs. Hill and I proceeded more slowly. About one-fourth of a mile from the station we were met by one of the men from the radio station, who had come to assist us had it been necessary. At 4:40 p. m. we arrived at the assistant lightkeeper's home where all the families of the Head had gathered for safety.

Such reports as are at hand indicate that while the low-pressure area was advancing from the Northwest, the high easterly or southeasterly winds attending the approach of the storm to the Washington coast moved northward along the coast, as a vessel report from off the Oregon coast, a considerable distance south of the North Head station, indicates that the lowest pressure and highest winds occurred several hours earlier than at the North Head station, in fact, at Point Reyes Light on the middle California coast, high winds occurred early in the forenoon.

At Tatoosh Island about 150 miles north of the mouth of the Columbia River, the lowest pressure and maximum wind velocity, 110 miles per hour, occurred about 7 p. m., several hours later than at North Head.

The recorded wind velocities at the North Head and Tatoosh Island stations were the highest ever observed at the respective stations, and judging from the damage to the forests of that region, are probably the highest that have occurred in the period covered by the growth of the oldest trees.

While the extent of the storm at the present time is uncertain, it appears that the entire coast district, probably from central Oregon to the Straits of Juan de Fuca, a distance of 200 miles or more, was swept by winds of hurricane velocity. How far inland these destructive winds extended is unknown at the present, but it seems probable they were limited to the western slopes of the mountains that follow the coast line a comparatively short distance therefrom.

Reports from Forest Service officials, who are in touch with conditions in the national forests in that locality, indicate that the damage to standing timber is the greatest ever experienced in the country. Billions of feet of the finest timber in the United States were uprooted or otherwise thrown down, much of which will be a total loss as it lies in regions not readily accessible for salvage.

Despite the severity of the winds, few lives are known to have been lost, and damage to property consisted mainly in the loss of timber.

Later reports, particularly from the cooperative observers of the bureau, located in the territory covered by the storm, will probably more fully outline its extent and comparative severity. Important facts covering these items will appear in a later REVIEW.

STORMS AND WARNINGS—WEATHER AND CROP.

STORMS AND WEATHER WARNINGS.

EDWARD H. BOWIE, Supervising Forecaster.

WASHINGTON FORECAST DISTRICT.

Storm warnings on Lake Michigan.—The season for the display of storm warnings closed on the Great Lakes in December, but because of there being more or less shipping on Lake Michigan advisory warnings of winds and weather dangerous to navigation are sent to open ports on that lake during the winter months. Such advices were issued on four occasions in January, namely, the 16th, 19th, 24th, and the 29th and 30th. That of the 16th for west and northwest gales, snow flurries, and colder weather was in connection with a well-defined disturbance that crossed the Great Lakes on this date. The highest velocity reported was 56 miles per hour at Grand Haven, Mich. On the morning of the 19th the warning was of southerly gales and rain, and these conditions occurred as forecast. On the morning of the 24th when a disturbance was central over Kansas and an area of high barometer of great magnitude had its crest north of Minnesota, increasing northeast and east winds probably reaching gale force, with snow, were forecast, while on the 29th and 30th advices of strong east and north winds and snow were issued in connection with a storm that was then moving eastward from Colorado.

Storm warnings on the Atlantic coast.—Advices of strong winds or gales were issued for sections of the Atlantic coast on the 9th, 10th, 13th, 14th, 16th, 17th, 20th, 26th, 27th, 30th, and 31st.

On the evening of the 9th, when a Gulf storm was central over Georgia and moving northeastward, northeast storm warnings were displayed on the coast from Cape Hatteras to Delaware Breakwater; and on the morning of the 10th the region of display of warnings was extended northward to Eastport, Me. Strong winds prevailed along the Middle Atlantic and southern New England coasts during the 10th and 11th.

The evening of the 13th southeast storm warnings were displayed at and between Charleston, S. C., and Boston, Mass., when an extensive area of low pressure was over the Mississippi Valley with steep barometric gradient to the eastward. On the 14th the display of warnings was extended northward to Eastport, Me., and the direction was changed to southwest at and between Boston, Mass., and Delaware Breakwater. Strong southerly winds and gales occurred during the 14th, the highest velocities being as follows: Wilmington, N. C., 30 south; Norfolk, Va., 44 south; Atlantic City, N. J., 32 south; New York, 68 southeast; Block Island, R. I., 48 south; Nantucket, Mass., 46 southeast; Boston, Mass., 32 south; and Portland, Me., 36 south.

A disturbance was central over the region of the Great Lakes the morning of the 16th and moving rapidly eastward. It was expected that it would increase in intensity, and therefore southwest storm warnings were displayed at 11 a. m. at all ports at and north of Cape Henry, Va. By the morning of the 17th this storm had moved to the Gulf of St. Lawrence, and westerly gales had occurred on the Middle Atlantic and New England coasts. The highest velocities reported were 84 at New York, 60 at Block Island, 44 at Nantucket, 38 at Boston, and 36 at Eastport.

The pressure was quite low the morning of the 20th over the Great Lakes, with the center of the low-pressure area north of Lake Huron.

At 10:30 a. m. southwest storm warnings were ordered displayed on the coast north of Sandy Hook. This disturbance moved rapidly eastward, and strong southwest winds and gales occurred on the New England coast during the afternoon and night of the 20th.

A storm of considerable intensity was, at the 8 p. m. observation of the 26th, over southeastern Georgia, and there were indications that it would move northeastward. Accordingly, northeast storm warnings were ordered displayed on the coast at and between Cape Henry and Wilmington, N. C. This storm moved as forecast, and strong winds and gales occurred over the area covered by warnings.

At 10 p. m. of the 30th northeast storm warnings were ordered for the coast at and north of Sandy Hook, N. J., and the morning of the 31st the display was extended south to Delaware Breakwater. Northeast gales set in during the early morning of the 31st on the New England coast, and there were strong northerly winds and snow on the New Jersey coast.

Storm warnings on the east Gulf coast.—No storm warnings were ordered, and there were no storm winds over the east Gulf during the month.

Cold-wave and frost warnings.—Frost warnings were issued on a number of days for the South Atlantic and east Gulf States. There were few cold waves during the month. Cold-wave warnings were issued on the 16th for the Northern States; on the 29th for Michigan and Indiana, and on the 31st for the Atlantic States north of Pennsylvania. No heavy snow warnings were issued during the month.

Chicago forecast district.—The month for the most part was unusually mild throughout the Chicago forecast district and only a few special warnings of any kind were necessary, the first being issued on the 15th and 16th, when a cold wave of moderate proportions overspread portions of North Dakota, Minnesota, Wisconsin, eastern Iowa, and the northern portions of Illinois and Missouri. No other cold-wave warnings were issued during the month, except for Williston, N. Dak., and Duluth, Minn., on the morning of January 29.

Advices to stock interests located on the eastern slope of the Rockies and the western portions of the Plains States were issued on January 10, 15, and 24, on the latter date heavy snow warnings also being issued for western Nebraska and northwestern Kansas.—*E. H. Haines.*

New Orleans forecast district.—Unseasonably mild weather prevailed and few warnings were needed.

No storm warnings were issued and no storms occurred except on the afternoon of the 14th, when northwest winds slightly exceeded the verifying velocity on the east coast of Texas. These winds occurred while a disturbance was moving east-southeast over the Great Lakes and an area of high pressure was stationary over Nevada and the Southwest, with isobars trending northwest-southeast over the Southern States. The barometric gradient was moderate.

A moderate cold wave occurred in Oklahoma on the 8th, for which warnings were issued the morning of the 7th.

Frost warnings for west Gulf coast sections were issued on the 1st, 8th, 9th, 14th, 15th, 25th, 26th, and 27th; and freezing nearly to the coast on the 26th. These warnings were nearly all verified.

Fire-weather warnings for the national forest areas of Oklahoma and Arkansas were issued on the 19th and conditions occurred mostly as forecast.—*R. A. Dyke.*

Denver forecast district.—North Pacific LOWS predominated, as in the preceding month, and unusually warm and dry weather prevailed in the greater part of the district. The winter, so far, has been notable for the absence of severe storms and low temperature.

Live-stock warnings were issued for eastern Colorado on the morning of the 10th, a south Pacific LOW of moderate intensity being central in Arizona and an area of high pressure in the north Pacific States and northern Rocky Mountain region. Temperatures near zero were reported in parts of Wyoming. Temperatures near zero occurred in localities in eastern Colorado on the 12th, preceded by snowfall. The live-stock warnings were extended to eastern New Mexico on the morning of the 11th. Snow, with temperatures well below the freezing point, occurred in eastern New Mexico on the 12th and 13th.

Moderate to heavy snowfall occurred in eastern Colorado on the 24th, following the unusual movement of an area of low pressure from the Gulf of California. The center of the disturbance was over northeast Arizona at 6 a. m. on the 23d. It moved southeastward to Roswell, N. Mex., by 6 p. m. of that date. During the following night the center moved almost directly northward to eastern Colorado, after which it again moved southeastward, being over Alabama, at 6 a. m. on the 25th. The temperatures following the snowfall were low in extreme eastern Colorado but moderate elsewhere.—*Frederick W. Brist.*

San Francisco forecast district.—January was an unusually stormy month in this district. The whole north Pacific Ocean was in a turmoil nearly all the while. The storms traveling inland passed farther south than customary, due largely to the fact that the pressure over northern Alaska was frequently above normal. On this account rain and heavy snow occurred in the Pacific States farther south than usual.

No less than 20 storm, four small-craft warnings, and one advisory warning were issued during the month. Practically all were verified in part, if not wholly. Casualities on sea and land were incommensurate with the violence of the storms; there being no bad disasters as yet reported at sea and no great interruption to traffic on land.

The worst storm was experienced along the north Pacific coast during the afternoon and evening of the 29th, when a maximum wind velocity of 110 miles from the southwest occurred at Tatoosh Island and an estimated velocity of 150 miles from the southeast at North Head was reported. The North Head station reported the anemometer there was destroyed by a falling wireless tower when it was recording 132 miles an hour, and that a conservative estimate of the maximum velocity for the storm was 150 miles. This is a record breaker, so far as that station is concerned.

The rains caused moderate freshets in the Sacramento River, but the stages reached by the water were not high enough to cause serious damage.

Frost warnings were issued on 18 days for parts of California. The heaviest frosts occurred on the mornings of the 9th, 10th, and 11th, and they did considerable damage to truck crops and citrus fruit. The citrus crop, however, as a whole was not seriously affected by the cold weather and at the close of the month it was in a promising condition.—*E. A. Beals.*

RIVERS AND FLOODS.

FLOODS DURING JANUARY, 1921.

By H. C. FRANKENFIELD, Meteorologist.

[Weather Bureau, Washington, Feb. 28, 1921.]

Atlantic drainage.—There were no floods north of North Carolina except a purely local one in the James River at Columbia, Va., on January 15. The flood came from the Rivanna River, and the flood stage was barely reached. No damage was done.

Heavy rains reported on January 10 caused moderate floods in the lower Roanoke River with a crest of 34.6 feet, 4.6 feet above the flood stage, at Weldon, N. C., on January 12. There was also a moderate flood at the same time in the Peedee River at Cheraw, S. C., with a crest of 27.2 feet, 0.2 foot above the flood stage. More heavy rains reported on January 14 resulted in a second flood in both of the above-mentioned rivers and also in the Neuse and Cape Fear Rivers, but the stages were not excessive. A third rise was forecast for the Peedee River from the melting of the heavy snows that fell over headwaters from January 25 to January 27, inclusive, and a crest stage of 25.2 feet was reached at Cheraw on the morning of February 2.

All of these floods were properly forecast and little or no damage occurred. Live stock, to the value of $5,000, was saved by the warnings for the Cape Fear River.

Moderate floods in the Broad and Wateree Rivers of South Carolina at about the same time were forecast as a whole, although with indifferent success for the Wateree River on account of lack of information as to the amount of water released at the Wateree Power Co. dam, about 9 miles above Camden. The same trouble apparently operated to cause the failure on January 28 of the forecast of 27 feet at Camden by January 29. This forecast was based upon the melting of the heavy snow and ice that accumulated over headwaters from January 25 to 27, inclusive.

The Santee River remained above flood stage throughout the entire month with no material damage. This river has been in flood for so long a period and the swamps are so full of water that little if any grazing could be carried on.

Gulf drainage.—The Tombigbee River was above flood stage of 39 feet at Demopolis, Ala., for about six days, beginning with January 14 and a crest stage of 43.8 feet was reached at 3 p. m. January 16. Warnings had been issued on January 12. Damage amounted to about $22,000, $20,000 of which covered the sinking of a towboat. Value of property saved through warnings, about $2,200.

High water prevailed in the Pearl River of Mississippi at the beginning and continued until well after the middle of the month.

A middle of the month flood in the upper Trinity River of Texas was well forecast. The flood was a moderate one and live stock was removed from the lowlands before its arrival.

Following heavy rains on January 12 and 13, floods were forecast for the Sulphur River of Texas, and stages from 2 to 3 feet above the flood stages were reached at the time specified in the warnings.

Pacific drainage.—Heavy rains on January 17 caused flood stages on the following day in the mountain tributaries of the Sacramento and Lower San Joaquin Rivers, and warnings were issued on the following day for the drainage canal interests at Stockton, and for the lower Mokelumne River; also for the Sacramento River between Monroeville and the mouth of the American River. Warnings for the upper valley were issued on January 17.

On the morning of January 29 heavy rains were in progress over the upper Sacramento Valley and advisory warnings of a substantial rise were issued in the early evening. More detailed and specific warnings were issued on the following morning, and also carried southward throughout the valley. These warnings were verified in the main, and no damage was done except in a few localities.

The Willamette River was in flood at the close of the year 1920 and did not fall below the flood stage at Portland, near the mouth of the river, until January 9, 1921. The crests varied from 3 to 4 feet above the flood stages. Warnings for the flood were issued at the proper time and the losses amounted to only about $21,000, of which about $20,000 occurred at Oregon City.

Flood stages during month of January, 1921.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage	Date.
ATLANTIC DRAINAGE.					
James:	*Feet.*			*Feet.*	
Columbia, Va.	18	15	15	18.0	15
Roanoke:					
Weldon, N. C.	30	12	13	34.6	12
Neuse:					
Neuse, N. C.	14	12	13	14.5	13
Do.	14	16	17	15.3	17
Smithfield, N. C.	14	15	18	14.7	16
Cape Fear:					
Elizabethtown, N. C.	22	12	14	25.4	13
Do.	22	16	18	26.5	17
Peedee:					
Cheraw, S. C.	27	12	12	27.2	12
Do.	27	16	16	32.5	16
Santee:					
Rimini, S. C.	12	(1)	7	13.5	1
Do.	12	12	(2)	16.2	20
Ferguson, S. C.	12	(1)	8	13.2	3
Do.	12	13	(2)	14.0	21
Wateree:					
Camden, S. C.	24	16	17	26.0	16
Broad:					
Blairs, S. C.	15	15	15	16.2	15 D. N
EAST GULF DRAINAGE.					
Apalachicola:					
River Junction, Fla.	12	(1)	1	12.3	1
Tombigbee:					
Demopolis, Ala.	39	(1)	3	44.5	1
Do.	39	15	19	43.8	16
Pearl:					
Jackson, Miss.	20	(1)	20	26.6	2
Columbia, Miss.	18	(1)	2	19.9	1
MISSISSIPPI DRAINAGE.					
Ouachita:					
Camden, Ark.	30	(1)	1	30.8	1
Sulphur:					
Finley, Tex.	24	17	23	26.3	17
Ringo Crossing, Tex.	20	14	19	23.5	15
WEST GULF DRAINAGE.					
Trinity:					
Dallas, Tex.	25	13	17	33.1	15
Trinidad, Tex.	28	15	25	34.4	22
PACIFIC DRAINAGE.					
Sacramento:					
Red Bluff, Calif.	23	30	30	24.4	30
Tuolumne:					
La Grange, Calif.	8	18	18	9.9	18
Mormon Slough:					
Bellota, Calif.	20	18	18	20.8	18
Calaveras:					
Jenny Lind, Calif.	14	18	18	15.0	18
Mokelumne:					
Bensons Ferry, Calif.	12	19	19	12.0	19
PACIFIC DRAINAGE—continued.					
Columbia:	*Feet.*			*Feet.*	
Vancouver, Wash.	15	5	6	15.5	6
Willamette:					
Eugene, Wash.	10	1	6	12.9	3
Albany, Oreg.	20	(1)	6	23.5	1
Oregon City, Oreg.	12	(1)	9	14.3	6,7
Portland, Oreg.	15	2	9	18.9	6
Santiam:					
Jefferson, Oreg.	10	2	5	13.0	3
Yamhill:					
McMinnville, Oreg.	35	6	6	37.9	6

[1] Continued from December.

[2] Continued into February.

[1] Continued from December.

MEAN LAKE LEVELS DURING JANUARY, 1921.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., Feb. 3, 1921.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during January, 1921:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.08	579.92	571.99	245.54
Above or below—				
Mean stage of December, 1920	−0.17	−0.18	+0.10	+0.14
Mean stage of January, 1920	+0.04	−0.12	+0.69	+0.23
Average stage for January, last 10 years	+0.03	−0.03	+0.36	+0.13
Highest recorded January stage	−0.70	−2.75	−1.56	−2.06
Lowest recorded January stage	+1.20	+0.84	+1.03	+1.74
Average relation of the January level to—				
December level	.....	−0.20	−0.10	0.00
February level	.....	0.00	+0.10	−0.10

[1] Lake St. Clair's level: In January, 574.98 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, JANUARY, 1921.

By J. WARREN SMITH.

January was characterized by persistent mild weather for the season in all sections of the country and no unusually low temperatures occurred. Precipitation was light, except in the central and north Pacific coast districts; considerable areas in the Southern States received less than 2 inches during the month. These conditions were unusually favorable for winter farm work and much plowing was done in the Southern States, particularly during the latter part, while the planting of early truck crops was under way in that section. There was considerable delay in farm work in the Pacific Coast States, however, due to persistent rains.

There was comparatively little snow protection to winter grains in the principal wheat growing sections, but, owing to the mild temperatures, no extensive damage occurred, although there was some complaint of alternate thawing and freezing in a few districts, principally in the upper Mississippi Valley. The month was generally favorable for winter truck, except for some frost damage in California and in portions of the South about the middle of the month. Western winter ranges were open for grazing during much of the month and ranges and stock continued mostly in good condition. Under the influence of the mild weather, fruit buds developed prematurely in the Southern States. Citrus fruits continued in satisfactory condition in both California and Florida.

CLIMATOLOGICAL TABLES.

DESCRIPTION OF TABLES AND CHARTS.

Table I gives the data ordinarily needed for climatological studies for about 174 Weather Bureau stations making simultaneous observations at 8 a. m. and 8 p. m. daily, 75th Meridian time, and for about 37 others making only one observation. The altitudes of the instruments above ground are also given.

The table showing the details of excessive precipitation, heretofore published as Table II, has been discontinued, and the Canadian data, formerly known as Table III, now becomes Table II. The details of excessive precipitation will hereafter appear only in the Annual Report of the Chief of the Weather Bureau.

Table II gives, for about 35 stations of the Canadian Meteorological Service, the means of pressure and temderature, total precipitation and depth of snowfall, and the respective departures from normal values except in the case of snowfall. The sea-level pressures have been computed according to the method described by Prof. F. H. Bigelow in the REVIEW of January, 1902, pages 13–16.

Chart I.—*Hydrographs* for several of the principal rivers of the United States.

Chart II.—*Tracks of centers* of HIGH areas; and

Chart III.—*Tracks of centers* of LOW areas. The Roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., 75th Meridian time. Within each circle is also given (Chart II) the last three figures of the highest barometric reading, or (Chart III) the lowest reading reported at or near the center at that time, and in both cases as reduced to sea-level and standard gravity.

Chart IV.—*Temperature departures.* This chart presents the departures of the monthly mean surface temperatures from the monthly normals. The normals used in computing the departures were computed for a period of 33 years (1873 to 1905) and are published in Weather Bureau Bulletin R, Washington, 1908. Stations whose records were too short to justify the preparation of normals in 1908 have been provided with normals as adequate records became available, and all have been reduced to the 33-year interval, 1873–1905. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly surface temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909.

Chart V.—*Total precipitation.* The scale of shades showing the depth is given on the chart. Whe𝔷 the monthly amounts are too small to justify shading and over sections of the country where stations are too widely separated, or the topography is too diversified to warrant reasonable accuracy in shading, the actual depths are given for a limited number of representative stations. Amounts less than 0.005 inch are indicated by the letter T, and no precipitation by 0.00.

Chart VI.—*Percentage of clear sky between sunrise and sunset.* The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

Chart VII.—*Isobars at sea-level, average surface temperatures, and prevailing wind directions.* The pressures have been reduced to sea-level and standard gravity by the method described by Prof. Frank H. Bigelow on pages 13–16 of the REVIEW for January, 1902. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of 8 a. m.—and 8 p. m.—readings at stations taking two observations daily, and to the 8 a. m.—or the 8 p. m.—observation, respectively, at stations taking but a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The sea-level temperatures are now omitted and average surface temperatures substituted. The isotherms can not be drawn in such detail as might be desired, for data from only the regular Weather Bureau stations are used.

The prevailing wind directions are determined from hourly observations at the great majority of the stations. A few stations having no self-recording wind-direction apparatus determine the prevailing direction from the daily or twice-daily observations only.

Chart VIII.—*Total snowfall.* This is based on the reports from regular and cooperative observers and shows the depth in inches of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures are also given. Chart VIII is published only when the snowfall is sufficiently extensive to justify its preparation.

Charts IX, X, etc.—*North Atlantic weather maps of particular days.*

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, January, 1921.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	50.0	+ 4.1	Evergreen	79	3	Florence	18	10†	3.23	−1.65	Gadsden	6.10	Silverhill	1.06
Arizona	43.2	+ 1.7	4 stations	81	9†	2 stations	− 5	12†	0.66	−0.69	Kingman	4.34	Indian Oasis	0.00
Arkansas	46.9	+ 5.7	Center Point	85	29	Gravette	6	14	2.07	−2.08	Arkansas City	3.87	2 stations	0.50
California	44.8	− 1.0	El Cajon	84	14	Madeline	−15	21	6.79	+1.38	Inskip	27.17	Mecca	0.15
Colorado	27.0	+ 3.7	Crawford	70	5	2 stations	−32	11†	0.97	+0.05	Cumbres	4.24	Garnett	T.
Florida	60.8	+ 2.0	2 stations	89	3†	DeFuniak Springs	28	15	1.37	−1.49	Glen St. Mary	3.93	Homestead	0.00
Georgia	49.9	+ 3.1	3 stations	78	5†	2 stations	21	16†	2.98	−0.96	Warrenton	5.53	Lumber City	0.64
Hawaii (December)	70.2	+ 0.5	Mahukona	90	13†	2 stations	48	13†	10.13	+1.40	Wahiawa Mtn	24.93	Makapuu Point	1.78
Idaho	27.0	+ 3.4	2 stations	60	5†	Stanley	−33	21	2.54	+0.18	Wallace	6.44	Challis	0.27
Illinois	34.1	+ 7.8	Mascoutah	68	21	4 stations	− 2	17	1.53	−0.93	Shawneetown	3.17	Rockford	0.12
Indiana	34.2	+ 5.6	2 stations	65	21†	4 stations	5	17†	2.45	−0.74	Salamonia	6.19	Plymouth	0.61
Iowa	28.4	+10.5	Albia	67	20	2 stations	− 9	12†	0.51	−0.54	Keokuk	1.92	Tipton	0.15
Kansas	36.9	+ 6.9	Medicine Lodge	76	15	Johnson	− 1	13	1.12	+0.37	Sedan	3.35	Jetmore	0.11
Kentucky	39.7	+ 4.5	Beattyville	71	4	Anchorage	12	27	3.06	−1.33	Brownsville	4.81	Carrollton	2.00
Louisiana	56.7	+ 5.8	Angola	84	6	Calhoun	23	10	3.09	−1.27	Simmesport	6.62	New Orleans (No. 8)	1.05
Maryland-Delaware	35.7	+ 3.1	2 stations	70	22	Oakland, Md	− 5	13	2.29	−1.02	Oakland, Md	4.15	Clear Spring, Md	1.05
Michigan														
Minnesota	17.6	+10.1	Beardsley	58	19	2 stations	−39	17	0.42	−0.35	International Falls	1.60	Faribault	0.00
Mississippi	51.7	+ 5.1	2 stations	80	5	Batesville	23	10	3.04	−2.00	Laurel	5.00	Pascagoula	1.11
Missouri	37.1	+ 7.2	Lockwood	74	21	Downing	− 1	17	1.88	−0.38	Birchtree	4.06	Kidder	0.51
Montana	26.2	+ 7.5	Big Timber	68	5	Bowen	−32	11	0.70	−0.31	Heron	4.68	3 stations	0.00
Nebraska	30.3	+ 8.4	Norfolk	69	19	2 stations	−12	26	0.74	+0.18	Chadron	1.97	O'Neill	0.10
Nevada	33.1	+ 2.6	Las Vegas	70	7	San Jacinto	−11	11	1.11	−0.22	Marlette Lake	4.05	Fallon	0.06
New England	24.0	+ 3.4	Waterbury, Conn	63	14	Pittsburg, N. H	−33	19	1.92	−1.48	Cream Hill, Conn	3.88	Cornwell, Vt	0.52
New Jersey	33.0	+ 3.0	Indian Mills	63	21	Culvers Lake	−11	25	2.63	−1.03	Dover	3.49	Hammonton	1.78
New Mexico	37.4	+ 2.9	Pearl (near)	79	19	Dulce	−21	14	0.62	−0.02	Gladstone	2.38	6 stations	0.00
New York	25.6	+ 2.7	Port Jervis	65	21	Raquette Lake	−33	19	1.67	−1.29	West Point	6.05	2 stations	0.13
North Carolina	42.3	+ 1.4	3 stations	77	22	Jefferson	7	19	4.12	+0.45	Southport	8.78	2 stations	1.50
North Dakota	16.1	+11.2	Dickinson	58	15	Bottineau	−31	11	0.22	−0.32	New England	0.75	3 stations	T.
Ohio	33.2	+ 4.7	Peebles	71	2	2 stations	3	13†	2.46	−0.69	Clarington	4.73	North Bass Island	0.86
Oklahoma	44.3	+ 5.7	2 stations	80	3†	Goodwell	4	13	2.00	+0.84	Blackwell	4.16	Wichita National Forest.	0.61
Oregon	36.3	+ 1.5	Dufur	66	14	Blitzen	−20	20	5.47	+0.74	Astoria	18.03	Heppner	0.72
Pennsylvania	31.0	+ 3.1	Lancaster	63	21	Bradford	−13	19	2.58	−0.66	Lycippus	5.23	Ansonia	0.89
Porto Rico	73.9	+ 0.7	Juncos	93	11	Cayey	51	1	6.24	+2.66	Conovanas	12.84	Potala	1.36
South Carolina	46.9	+ 1.3	Darlington	79	23	Society Hill	17	25	3.84	+0.39	Laurens	7.16	Ferguson	1.31
South Dakota	26.0	+10.5	Spearfish	79	19	Pollock	−19	12	0.41	−0.20	Hot Springs	2.10	2 stations	T.
Tennessee	43.1	+ 4.3	Savannah	74	22	Mountain City	9	16	3.34	−1.56	Decatur	5.10	Memphis	1.84
Texas	54.1	+ 5.7	Cuero	92	7	Romero	4	13	1.79	+0.04	Beaumont	6.00	3 stations	0.00
Utah	29.2	+ 3.7	2 stations	63	4†	East Portal	−34	12	1.58	+0.05	Silver Lake	7.15	Manila	0.00
Virginia	38.2	+ 2.2	Franklin	75	2	Burkes Garden	−12	11	3.12	−0.12	Blacksburg	5.62	Winchester	1.17
Washington	33.5	+ 3.2	Tahola	63	21	Snyders Ranch	−11	11	6.21	−1.06	Forks	29.70	Hanford	0.36
West Virginia	35.5	+ 3.3	2 stations	71	1	2 stations	− 2	13	2.76	−0.99	Terra Alta	5.94	Upper Tract	0.10
Wisconsin	22.7	+ 8.5	Racine	57	20	2 stations	−25	12	0.51	−0.67	Mondovi	1.65	2 stations	0.02
Wyoming	23.3	+ 3.8	2 stations	63	5†	Gallatin	−40	10†	0.87	−0.04	Fort Laramie	2.47	2 stations	T.

* For description of tables and charts, see this REVIEW, page 41.

† Other dates also.

TABLE I.—*Climatological data for Weather Bureau Stations, January, 1921*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Precipitation.			Wind.										
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Maximum velocity: Direction.	Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
New England.							**27.6**	**+3.1**										**73**	**2.04**	**− 1.5**										**6.0**		
Eastport	76	67	85	29.94	30.02	+0.02	23.4	+ 3.3	49	15	31	− 6	19	16	36	21	15	70	2.10	− 1.7	10	9,966	nw.	47	s.	15	9	7	15	6.3	7.5	T.
Greenville, Me	1,070	6		28.83	30.04		15.2		39	15	25	−16	18	6	33				1.48		9						12	8	11		13.8	22.0
Portland, Me	103	82	117	29.96	30.09	+ .04	26.3	+ 4.3	48	15	34	− 3	25	18	33	23	17	69	1.83	− 2.0	11	7,291	nw.	46	nw.	25	14	2	15	5.0	4.2	1.7
Concord	288	70	79	29.77	30.10	+ .05	23.3	+ 2.1	48	2	33	− 6	19	13	40				1.58	− 1.8	11	3,913	nw.	24	nw.	17	13	5	13	5.3	5.9	4.1
Burlington	404	11	48	29.65	30.12	+ .07	21.4	+ 5.1	44	2	30	−10	19	13	35				0.65	− 1.2	11	10,841	s.	62	s.	20	7	8	16	6.8	2.8	T.
Northfield	876	12	60	29.12	30.12	+ .07	18.6	+ 3.5	46	2	30	−23	19	8	50	15	12	81	0.69	− 1.8	12	6,643	s.	35	s.	20	7	6	18	6.7	7.2	14.0
Boston	125	115	188	29.95	30.09	+ .04	32.1	+ 5.1	56	14	40	0	25	24	32	28	21	66	2.24	− 1.6	12	8,559	w.	39	nw.	25	10	9	12	5.5	3.6	0.4
Nantucket	12	14	90	30.07	30.08	+ .04	32.6	+ 0.5	53	2	39	2	25	26	30	31	28	83	2.23	− 1.2	13	12,689	w.	55	w.	17	6	8	17	6.8	0.9	T.
Block Island	26	11	46	30.08	30.11	+ .04	33.4	+ 2.0	55	14	40	4	25	27	31	31	27	78	2.61	− 1.2	11	16,583	nw.	60	nw.	17	7	8	16	6.4	1.9	0.4
Providence	160	215	251	29.92	30.10	+ .04	31.2	+ 4.0	55	15	40	0	25	23	34	28	22	73	3.32	− 1.1	11	10,500	nw.	60	w.	17	10	9	12	5.5	1.6	0.7
Hartford	159	122	140	29.95	30.13	+ .06	30.0	+ 0.5	54	14	38	− 1	25	22	31	26	20	68	2.41	− 1.4	9	6,268	nw.	35	w.	17	9	7	15	6.0	2.3	0.7
New Haven	106	74	153	30.02	30.14	+ .06	31.0	+ 3.7	52	23	39	1	25	23	27	28	22	71	2.78	− 1.1	10	7,599	n.	36	w.	17	10	9	12	5.4	3.7	0.7
Middle Atlantic States.							**34.8**	**+ 3.3**										**72**	**2.16**	**− 1.1**										**5.8**		
Albany	97	102	115	30.03	30.15	+ .08	27.4	+ 4.9	53	2	36	− 4	18	19	28	24	21	78	0.66	− 1.9	12	6,547	s.	44	s.	16	11	11	9	4.8	1.3	0.5
Binghamton	871	10	84	29.19	30.15	+ .07	27.3	+ 4.2	51	21	35	− 3	19	20	33				1.68	− 0.3	15	4,973	nw.	32	nw.	17	7	7	17	6.5	6.0	2.5
New York	314	414	454	29.80	30.15	+ .05	33.6	+ 3.4	55	2	41	4	25	26	28	29	22	65	1.65	− 2.1	7	15,555	nw.	84	nw.	17	9	10	12	5.9	2.6	0.5
Harrisburg	374	94	104	29.78	30.19	+ .09	32.0	+ 3.3	54	2	39	5	19	26	25	28	23	70	1.68	− 1.1	11	5,218	w.	40	w.	17	8	8	15	5.9	3.1	0.6
Philadelphia	117	123	190	30.05	30.18	+ .07	36.0	+ 4.2	61	2	43	7	19	29	31	33	29	80	2.03	− 1.4	9	7,954	nw.	35	s.	14	10	5	16	6.1	2.2	1.5
Reading	325	81	98	29.82	30.19		32.9		56	2	40	5	19	26	24	29	23	69	2.79	− 0.7	10	4,757	nw.	26	nw.	5	8	5	18	6.4	2.5	0.5
Scranton	805	111	119	29.27	30.17	+ .08	29.4	+ 3.8	50	21	37	1	19	22	29	26	22	77	2.02	− 0.8	12	5,921	sw.	44	w.	17	11	14	6	5.1	3.6	0.5
Atlantic City	52	37	48	30.11	30.17	+ .06	35.8	+ 3.3	58	23	42	8	19	29	24	32	27	72	1.91	− 1.5	9	6,116	nw.	34	s.	14	11	6	14	5.7	0.5	0.5
Cape May	18	13	49	30.19	30.21	+ .09	36.4	+ 2.3	57	23	43	7	19	30	21	33	28	76	1.79	− 1.6	7	7,622	nw.	36	nw.	12	14	5	12	5.1	T.	T.
Sandy Hook	22	10	55	30.13	30.16		33.7		54	14	40	8	25	28	27	31	26	76	2.06		10	14,359	sw.	55	w.	17	9	10	12	5.7	3.3	1.5
Trenton	190	159	183	29.95	30.16		33.4		58	2	41	4	19	26	32	29	24	72	2.41	− 0.8	9	8,638	w.	44	w.	17	10	7	14	6.0	2.2	0.8
Baltimore	123	100	113	30.05	30.19	+ .07	37.0	+ 3.6	66	21	44	10	19	30	30	32	25	64	2.05	− 1.2	9	4,240	sw.	26	sw.	17	9	7	15	6.4	0.2	0.2
Washington	112	62	85	30.06	30.19	+ .06	36.6	+ 3.7	67	22	44	11	19	29	30	31	24	64	2.30	− 1.1	9	5,175	n.	33	nw.	5	8	8	15	6.4	1.5	T.
Lynchburg	681	153	188	29.43	30.20	+ .07	39.0	+ 3.2	67	22	48	13	19	30	36	34	28	68	2.60	− 1.1	6	5,797	w.	35	nw.	5	13	9	9	5.2	11.9	0.0
Norfolk	91	170	205	30.09	30.19	+ .06	43.6	+ 3.2	71	22	52	20	19	36	28	38	32	67	1.55	− 1.8	3	11,100	ne.	54	ne.	10	10	9	12	5.9	T.	0.0
Richmond	144	11	52	30.04	30.21	+ .08	39.9	+ 1.9	69	22	49	15	19	31	32	35	30	74	3.80	+ 0.8	7	6,851	s.	34	n.	10	8	10	13	6.4	T.	0.0
Wytheville	2,304	49	56	27.76	30.23	+ .09	33.8	+ 0.8	62	1	43	8	11	25	32	30	26	76	3.65	− 0.7	12	5,923	w.	35	nw.	17	10	9	12	5.6	20.1	T.
South Atlantic States.							**47.9**	**+ 2.7**										**75**	**2.96**	**− 0.8**										**5.8**		
Asheville	2,255	70	84	27.81	30.25	+ .10	39.1	+ 3.7	65	4	48	20	19	30	36	34	29	74	3.35	− 1.3	11	6,520	nw.	35	nw.	17	7	10	14	6.4	10.6	0.0
Charlotte	779	55	62	29.35	30.21	+ .06	42.2	+ 1.8	71	22	51	21	19	34	35	37	32	72	5.22	+ 0.9	10	4,770	sw.	26	w.	5	8	8	15	6.5	4.7	T.
Hatteras	11	12	50	30.15	30.16	+ .02	47.8	+ 2.0	65	14	54	30	26	42	20	44	42	84	1.65	− 3.3	8	12,862	n.	49	nw.	10	8	12	11	5.9	T.	0.0
Manteo	12	5	42																													
Raleigh	376	103	110	29.79	30.21	+ .08	42.6	+ 2.2	72	22	51	17	19	34	33	36	29	65	3.97	+ 0.4	9	6,892	ne.	38	nw.	5	6	10	15	6.5	7.0	T.
Wilmington	78	81	91	30.12	30.21	+ .07	48.4	+ 2.8	74	22	58	23	19	39	33	42	37	74	4.16	+ 0.7	8	5,957	w.	38	ne.	27	9	13	9	5.2	0.0	0.0
Charleston	48	11	92	30.15	30.20	+ .05	51.7	+ 2.4	73	22	60	30	19	43	27	46	42	80	1.58	− 1.9	10	8,344	sw.	34	nw.	27	10	12	9	5.2	0.0	0.0
Columbia, S. C	351	41	57	29.83	30.23	+ .08	47.0	+ 1.9	74	22	56	25	19	37	38	41	36	73	3.26	0.0	7	5,500	w.	23	sw.	5	12	6	13	5.6	0.0	0.0
Due West, S. C	711	10	55	29.45	30.24		44.2		71	23	54	22	26	35	36				3.93		10	6,792	sw.	30	ne.	9	9	8	14	6.0	0.8	0.0
Greenville, S. C	1,039	113	122	29.08	30.20		43.8		72	22	52	22	26	35	36	38	33	72	5.10		10	6,952	ne.	36	w.	5	7	12	12	5.9	2.0	0.0
Augusta	180	62	77	30.01	30.21	+ .05	48.4	+ 2.5	73	5	59	26	27	38	38	42	38	74	2.84	− 1.3	9	4,046	nw.	22	nw.	9	9	8	14	5.8	0.2	0.0
Savannah	65	150	194	30.14	30.21	+ .06	53.6	+ 3.7	72	23	62	30	27	45	27	46	42	76	1.48	− 1.6	8	9,436	sw.	38	w.	15	9	11	11	6.1	0.5	0.0
Jacksonville	43	209	245	30.16	30.21	+ .06	58.0	+ 4.1	74	30	66	34	27	50	23	52	49	80	2.01	− 1.1	4	9,327	n.	39	nw.	27	14	10	7	4.3	0.0	0.0
Florida Peninsula.							**67.2**	**+ 1.8**										**78**	**1.23**	**− 1.5**										**4.6**		
Key West	22	10	64	30.13	30.15	+ .05	70.6	+ 1.8	83	3	75	56	16	66	17	65	62	81	1.88	− 0.1	6	8,507	ne.	39	n.	14	16	9	6	4.3	0.0	0.0
Miami	25	71	79	30.15	30.18		67.8	+ 0.5	80	3	74	44	28	61	25	62	59	75	0.73	− 2.7	9	6,519	e.	35	nw.	27	13	12	6	4.6	0.0	0.0
Sand Key	23	39	72	30.10	30.13	+ .03	70.0		78	3	73	59	28	67	12	66	63	78	1.29		7	13,209	ne.	50	n.	14	11	14	6	4.5	0.0	0.0
Tampa	35	79	92	30.16	30.20	+ .08	63.1	+ 3.0	80	4	72	43	11	54	31	56	52	79	1.07	− 1.7	7	4,561	nw.	25	sw.	14	11	14	6	4.8	0.0	0.0
East Gulf States.							**52.4**	**+ 0.5**										**74**	**2.69**	**− 2.3**										**5.4**		
Atlanta	1,174	190	216	28.95	30.22	+ .07	45.9	+ 3.7	67	23	54	27	27	38	32	41	35	71	3.53	− 1.8	9	8,741	nw.	36	nw.	5	8	7	16	6.1	0.6	0.0
Macon	370	78	87	29.82	30.22	+ .06	49.4	+ 3.8	72	5	60	28	27	39	35	43	38	72	1.75	− 3.4	10	4,732	nw.	24	s.	9	9	9	13	5.5	T.	0.0
Thomasville	273	49	58	29.91	30.21	+ .05	55.6	+ 4.6	74	22	66	35	27	46	30	49	45	76	2.39	− 1.7	7	3,539	sw.	20	w.	15	12	7	12	5.4	0.0	0.0
Pensacola	56	149	185	30.16	30.22	+ .08	56.0	+ 3.7	70	17	63	33	10	49	26	51	48	80	1.67	− 2.4	4	9,190	sw.	40	n.	3	9	12	10	5.5	0.0	0.0
Anniston	741	9	57	29.42	30.23	+ .07	46.8	+ 4.6	69	23	57	27	28	37	35				3.83	− 1.5	13	4,476	nw.	34	se.	13	11	12	8	5.3	0.5	0.0
Birmingham	700	11	48	29.45	30.24	+ .08	49.3	+ 4.0	71	23	58	28	10	40	33	42	37	69	3.72	− 1.6	12	5,365	n.	38	se.	13	9	13	9	5.8	T.	0.0
Mobile	57	125	161	30.15	30.21	+ .06	56.0	+ 7.2	74	30	65	35	10	47	26	48	46	76	1.89	− 3.0	7	7,124	s.	38	nw.	9	6	20	5	4.9	0.0	0.0
Montgomery	223	100	112	29.98	30.23	+ .07	52.7	+ 5.0	73	5	62	33	27	43	34	46	40	69	2.84	− 2.3	9	4,762	n.	25	se.	13	14	8	9	4.9	0.0	0.0
Corinth	469	6					47.3		73	22	57	24	10	38	36				2.63		12		s.				3	18	10		T.	0.0
Meridian	375	85	93	29.81	30.22	+ .06	51.3	+ 6.3	73	24	61	28	28	42	33	45	41	74	3.27	− 2.3	6	4,366	sw.	24	sw.	14	11	10	10	5.6	0.0	0.0
Vicksburg	247	65	73	29.94	30.22	+ .07	53.8	+ 6.8	74	1	62	33	27	45	28	47	43	74	3.55	− 2.1	7	5,740	se.	36	w.	1	9	11	11	5.5	0.0	0.0
New Orleans	53	76	84	30.16	30.22	+ .09	59.2	+ 6.2	76	8	67	37	27	51	24	53	50	80	1.16	− 3.5	6	4,031	sw.	20	nw.	14	10	13	8	4.8	0.0	0.0
West Gulf States.							**53.6**	**+ 7.4**										**76**	**2.22**	**− 0.7**										**5.9**		
Shreveport	249	77	93	29.93	30.21	+ .07	53.4	+ 7.2	77	4	62	30	27	44	30	47	42	74	4.18	− 0.2	8	5,959	se.	29	w.	1	14	9	8	4.8	0.0	0.0
Bentonville	1,303	11	44	28.74	30.14	.00	42.8	+ 8.7	69	7	51	18	15	34	33				1.48	− 1.2	11	5,244	s.	26	s.	19	5	6	20	6.9	5.5	0.0
Fort Smith	457	79	94	29.67	30.17	+ .03	45.6	+ 7.3	72	7	54	25	14	37	30	40	34	69	1.39	− 1.1	9	6,630	e.	38	sw.	7	8	5	18	6.9	4.3	0.0
Little Rock	357	136	144	29.80	30.18	+ .03	47.2	+ 6.6	71	7	55	29	13	39	29	42	37	72	1.52	− 3.3	6	6,753	s.	37	s.	7	6	11	14	6.7	0.2	0.0
Brownsville	57	4	26				65.8		84	25	76	38	15	55	38				2.26		12		se.									
Corpus Christi	20	69	77	30.14	30.16	+ .06	63.0	+ 9.5	80	29	70	40	15	56	37	57	54	81	2.07	− 0.2	6	8,268	s.	37	ne.	8	7	11	13	6.4	0.0	0.0
Dallas	512	109	117	29.61	30.17		52.0		81	4	62	29	27	42	37				3.15		6	6,918	se.	30	s.	7	9	12	10	5.4	2.1	0.0
Fort Worth	670	106	114	29.43	30.16	+ .04	51.4	+ 7.1	81	4	61	28	27	42	40	46	40	68	2.87	+ 1.9	5	7,971	nw.	31	s.	19	9	10	12	5.6	0.2	0.0
Galveston	54	106	114	30.14	30.20	+ .07	58.2	+ 5.5	71	5	63	42	27	54	20	56	54	80	2.77	− 0.8	6	8,650	se.	37	nw.	14	9	9	13	6.1	0.0	0.0
Groesbeck	461	11	56	29.67	30.16		54.0		78	7	64	29	27	44	41				1.61		7	8,412	s.	32	sw.	7	7	11	13	5.7	0.0	0.0
Houston	138	111	121	30.03	30.18		59.2	+ 6.3	78	7	67	35	27	51	28				3.58		8	6,935	se.	28	s.	20	11	17	3	4.4	0.0	0.0
Palestine	510	64	72	29.64	30.19	+ .07	54.6	+ 8.1	78	7	64	29	27	46	34	48	44	75	2.37	− 1.5	6	6,270	se.	25	nw.	14	7	10	14	6.0	0.0	0.0
Port Arthur	34	58	66	30.14	30.18		57.7		75	5	64	35	27	51	21	54	52	87	1.60		9	7,304	se.	36	nw.	14	8	10	13	6.0	0.0	0.0
San Antonio	701	119	132	29.42	30.15	+ .05	58.4	+ 7.3	81	5	68	34	27	48	34	52	46	71	1.40	− 0.3	11	6,238	se.	28	nw.	14	14	6	11	4.9	0.0	0.0
Taylor	582	55	63	29.57	30.19	+ .08	55.4	+ 7.9	79	7	66	31	27	45	42				2.17	− 0.6	7	6,725	n.	27	s.	6	10	2	19	6.4	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau Stations, January, 1921*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.													Precipitation.			Wind.										
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Maximum velocity: Direction.	Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0–10	In.	In.
Ohio Valley and Tennessee.							38.4	+ 5.4										74	2.74	− 1.1										6.6		
Chattanooga	762	189	213	29.41	30.24	+ .08	44.1	+ 3.5	66	21	52	27	26	36	37	38	32	68	4.46	− 1.1	13	5,599	nw.	34	sw.	1	6	14	11	6.4	9.7	0.0
Knoxville	996	102	111	29.13	30.22	+ .07	41.9	+ 4.4	67	1	50	23	16	34	34	37	32	74	3.40	− 1.6	10	4,691	ne.	28	sw.	1	5	15	11	6.6	5.3	0.0
Memphis	399	76	97	29.80	30.24	+ .08	47.2	+ 6.9	68	22	54	27	15	40	23	42	37	71	1.84	− 3.4	8	6,758	s.	32	w.	1	11	4	16	6.0	0.1	0.0
Nashville	546	168	191	29.63	30.23	+ .06	43.2	+ 5.7	69	21	51	22	27	36	29	38	33	70	3.11	− 1.7	10	7,420	nw.	41	se.	29	7	9	15	6.7	7.8	0.0
Lexington	989	193	230	29.11	30.21	+ .08	37.4	+ 4.4	62	1	45	16	17	30	25	....	....	....	3.24	− 0.6	13	11,731	sw.	47	sw.	1	9	5	17	6.5	9.8	0.0
Louisville	525	219	255	29.62	30.22	+ .08	39.2	+ 4.9	63	21	46	18	17	33	21	35	31	76	2.20	− 1.7	10	10,082	s.	42	s.	1	10	6	15	6.0	3.9	0.0
Evansville	431	139	175	29.73	30.21	+ .07	39.4	+ 7.1	63	21	46	18	17	33	23	35	30	73	1.80	− 1.9	11	9,126	sw.	33	sw.	1	3	12	16	7.0	3.0	0.0
Indianapolis	822	194	230	29.26	30.17	+ .05	34.3	+ 6.1	54	1	41	10	17	28	22	31	27	77	2.86	0.0	12	9,794	s.	33	nw.	16	5	9	17	6.9	4.9	0.6
Royal Center	736	11	55	29.33	30.16	......	31.6	......	53	1	38	8	17	25	25	....	....	....	2.45	......	11	8,667	sw.	39	w.	16	7	7	17	6.7	4.4	3.0
Terre Haute	575	96	129	29.52	30.16	......	35.5	......	57	1	42	10	17	29	23	32	28	77	1.67	......	11	8,111	s.	34	s.	1	5	9	17	7.0	4.8	0.0
Cincinnati	628	11	51	29.50	30.20	+ .08	35.9	+ 5.6	61	1	43	14	17	29	24	....	30	78	1.72	− 1.6	12	7,012	sw.	29	w.	5	9	6	16	6.2	1.9	0.0
Columbus	824	179	222	29.29	30.19	+ .08	33.8	+ 5.2	59	1	41	14	18	27	26	31	26	76	2.19	− 0.8	14	9,292	sw.	55	w.	16	10	7	14	6.1	1.3	0.4
Dayton	899	181	216	29.16	30.15	......	34.7	+ 5.8	58	1	41	13	17	28	25	31	27	76	2.59	− 0.4	9	8,822	sw.	37	nw.	16	11	6	14	6.2	4.1	1.6
Elkins	1,947	59	67	28.08	30.22	+ .10	35.0	+ 6.0	63	1	45	3	13	25	40	30	26	78	2.50	− 0.8	16	4,847	w.	33	w.	16	4	11	16	6.9	5.9	0.0
Parkersburg	638	77	84	29.53	30.21	+ .09	37.4	+ 6.1	66	1	46	16	18	29	31	32	26	70	3.17	0.0	15	4,677	se.	36	w.	2	9	6	16	6.5	2.7	T.
Pittsburgh	842	353	410	29.24	30.18	+ .07	34.6	+ 3.9	59	4	42	9	25	27	23	31	26	72	3.35	+ 0.5	16	9,101	sw.	56	w.	16	4	8	19	7.3	2.4	1.8
Lower Lake Region.							29.4	+ 4.9										76	1.08	− 1.6										6.8		
Buffalo	767	247	280	29.27	30.13	+ .06	29.1	+ 4.4	53	2	35	0	19	23	31	25	22	77	0.89	− 2.4	14	14,976	w.	74	w.	17	4	10	17	7.5	2.5	0.1
Canton	448	10	61	29.60	30.11	......	20.9	+ 4.6	47	4	30	−15	19	12	34	....	....	....	1.22	− 1.9	11	8,763	sw.	55	sw.	20	12	7	12	5.1	6.3	0.2
Oswego	335	76	91	29.74	30.13	+ .06	25.6	+ 2.7	48	20	34	− 6	19	19	30	24	22	81	0.60	− 2.6	13	9,823	s.	42	nw.	17	3	10	18	7.5	3.9	0.0
Rochester	523	86	102	29.55	30.14	+ .07	29.2	+ 5.2	50	21	35	1	19	22	25	25	20	71	0.52	− 2.6	13	7,943	sw.	39	sw.	2	4	9	18	7.2	1.5	T.
Syracuse	597	97	113	29.48	30.15	+ .08	27.3	+ 3.3	51	4	35	− 9	18	20	27	....	....	....	1.02	− 1.1	14	9,655	s.	46	s.	14	4	8	19	7.3	3.0	T.
Erie	714	130	166	29.34	30.14	+ .07	31.4	+ 4.9	57	1	38	4	19	25	32	28	24	74	1.59	− 1.4	18	12,585	nw.	54	w.	16	6	2	23	7.5	10.7	3.5
Cleveland	762	190	201	29.31	30.16	+ .07	32.0	+ 5.8	56	1	38	10	19	25	28	29	25	76	1.53	− 0.9	19	11,435	s.	60	w.	16	7	6	18	7.2	4.2	1.8
Sandusky	629	62	103	29.45	30.16	+ .07	32.8	+ 6.5	56	1	38	13	18	27	23	....	....	....	1.59	− 0.5	14	10,604	sw.	50	w.	16	7	8	16	6.7	2.2	1.6
Toledo	628	208	243	29.46	30.16	+ .07	31.8	+ 6.2	54	4	38	9	18	25	23	29	24	75	1.53	− 0.4	12	11,473	sw.	52	w.	16	8	8	15	6.2	2.8	1.9
Fort Wayne	856	113	124	29.21	30.17	......	31.6	+ 4.7	54	1	38	11	18	25	23	29	24	76	2.11	......	11	8,042	sw.	38	w.	16	6	8	17	6.7	6.0	3.5
Detroit	730	218	245	29.33	30.15	+ .07	30.4	+ 6.1	50	20	36	9	18	25	18	28	24	78	0.28	− 1.7	8	9,762	sw.	48	sw.	2	10	6	15	5.9	0.8	0.0
Upper Lake Region.							25.2	+ 7.3										80	0.90	− 1.1										6.9		
Alpena	609	13	92	29.41	30.10	+ .05	25.2	+ 6.5	47	20	31	6	17	19	31	23	20	83	0.82	− 1.4	9	8,836	w.	48	se.	19	1	12	18	7.5	3.7	T.
Escanaba	612	54	60	29.41	30.10	+ .05	23.0	+ 8.5	47	20	30	− 1	18	16	25	21	18	83	0.89	− 0.7	9	6,891	nw.	30	n.	30	9	8	14	6.2	8.9	1.0
Grand Haven	632	54	89	29.42	30.13	+ .06	29.2	+ 4.7	48	1	35	9	17	24	26	27	24	79	0.69	− 2.1	13	10,458	w.	68	w.	16	9	6	16	6.6	4.2	0.0
Grand Rapids	707	70	87	29.34	30.14	+ .08	30.5	+ 6.7	52	20	[illegible]	11	18	25	27	27	22	74	0.59	− 2.2	10	5,359	w.	38	nw.	16	8	9	14	6.4	1.1	0.0
Houghton	684	62	99	29.32	30.07	+ .02	21.0	+ 6.5	45	19	28	− 4	13	14	32	....	....	....	2.93	+ 0.9	13	7,927	w.	55	w.	20	3	6	22	8.2	30.7	14.5
Lansing	878	11	62	29.15	30.13	......	29.2	......	53	20	[illegible]	6	18	22	25	[illegible]	23	82	0.41	− 1.7	9	5,902	sw.	30	nw.	16	4	9	18	7.3	1.7	0.0
Ludington	637	60	66	29.39	30.11	......	28.6	......	43	1	34	8	25	24	24	26	23	79	0.42	......	11	9,454	w.	54	w.	16	6	8	17	7.0	4.0	0.0
Marquette	734	77	111	29.28	30.11	+ .07	23.4	+ 7.5	49	20	30	1	13	17	22	21	17	81	2.28	+ 0.2	13	7,801	w.	37	sw.	20	4	7	20	7.6	24.4	8.4
Port Huron	638	70	120	29.41	30.13	+ .07	28.6	+ 6.8	53	20	35	6	25	22	25	25	23	82	0.35	− 1.5	9	9,371	sw.	48	w.	16	8	9	14	6.4	2.1	0.0
Saginaw	641	69	77	29.41	30.13	......	28.7	......	53	20	35	8	17	23	29	26	22	78	0.38	− 1.9	7	7,638	sw.	35	w.	16	4	13	14	7.0	0.9	0.0
Sault Ste. Marie	614	11	52	29.38	30.12	+ .09	19.8	+ 6.5	44	20	27	− 9	25	12	37	18	14	81	1.35	− 0.8	12	6,679	se.	36	nw.	23	4	8	19	7.4	10.5	5.7
Chicago	823	140	310	29.23	30.15	+ .05	32.4	+ 8.7	56	21	38	8	17	27	22	30	25	73	0.97	− 0.1	9	10,152	w.	37	w.	2	12	9	10	5.4	3.2	2.0
Green Bay	617	109	144	29.42	30.12	+ .06	24.1	+ 9.5	44	19	30	0	12	18	24	22	18	76	0.50	− 1.2	7	8,902	w.	48	w.	16	3	11	17	7.5	4.4	0.0
Milwaukee	681	125	139	29.36	30.12	+ .04	29.1	+ 9.3	53	21	35	2	12	23	20	25	22	75	0.22	− 1.8	4	8,361	w.	32	sw.	19	9	7	15	6.3	1.8	0.0
Duluth	1,133	11	47	28.82	30.10	+ .01	16.6	+ 6.2	43	19	24	−17	12	9	30	15	13	89	0.18	− 0.8	5	9,489	sw.	59	nw.	16	9	8	14	6.2	2.0	2.0
North Dakota.							15.8	+11.8										83	0.40	− 0.4										5.7		
Moorhead	940	50	58	29.59	30.13	− .01	15.3	+12.6	43	19	24	−17	12	7	30	13	11	85	1.21	− 0.5	6	6,567	s.	36	nw.	15	5	9	17	6.8	10.6	2.3
Bismarck	1,674	8	57	28.24	30.11	− .02	18.8	+12.1	54	15	30	−10	16	8	46	16	13	81	0.12	− 0.4	2	6,598	nw.	39	s.	18	8	14	9	5.2	2.5	2.2
Devils Lake	1,482	11	44	28.42	30.08	− .04	10.5	+10.2	39	20	20	−22	17	1	34	9	8	90	0.13	− 0.5	5	8,033	nw.	38	nw.	15	10	9	12	5.4	2.0	2.5
Ellendale	1,457	10	56	28.48	30.10	......	19.2	......	55	19	30	−10	17	8	39	....	....	....	0.16	......	3	10,808	nw.	53	w.	19	10	9	12	5.7	1.4	1.1
Grand Forks	835	12	89	......	......	......	12.0	......	38	19	22	−18	17	2	30	....	....	....	0.38	......	4	......	s.	56	sw.	18	12	11	8	....	3.7	3.6
Williston	1,878	41	48	27.96	30.03	− .08	18.7	+12.2	44	5	29	− 8	11	9	34	16	12	75	0.15	− 0.4	2	5,741	se.	30	nw.	15	10	9	12	5.4	0.7	0.2
Upper Mississippi Valley.							31.0	+ 9.5										78	0.97	− 0.8										6.5		
Minneapolis	918	102	208	29.08	30.10	......	22.0	......	49	19	30	− 8	17	15	28	....	....	....	0.44	− 0.2	6	8,924	w.	41	w.	16	3	9	19	7.0	3.4	0.8
St. Paul	837	236	251	29.18	30.12	+ .01	21.4	+ 9.8	48	19	29	− 8	12	14	30	....	....	....	0.59	− 0.3	7	9,449	se.	45	nw.	16	4	12	15	6.4	4.4	1.0
La Crosse	714	11	48	29.32	30.12	+ .01	25.2	+10.0	50	20	32	− 3	17	18	31	....	....	....	0.71	− 0.4	7	4,001	w.	22	nw.	16	7	7	17	7.0	5.2	T.
Madison	974	70	78	29.06	30.16	+ .05	25.4	+ 8.9	51	21	32	− 1	17	19	24	24	22	88	0.22	− 1.3	4	7,510	nw.	34	s.	19	6	11	14	6.4	3.0	0.7
Wausau	1,247	4	......	28.70	30.10	......	20.3	......	44	19	27	− 8	12	13	28	....	....	....	0.50	......	5	......	nw.	......	......	......	9	7	15	6.4	4.5	2.0
Charles City	1,015	10	49	29.02	30.14	.00	24.0	+12.6	47	20	31	− 5	17	17	30	22	20	87	0.58	− 0.4	5	5,145	nw.	25	s.	16	4	9	18	7.6	6.6	1.0
Davenport	606	71	79	29.48	30.16	+ .04	31.2	+10.4	57	20	38	2	17	24	26	28	24	78	0.47	− 1.1	8	5,724	w.	30	e.	24	9	9	13	5.6	3.5	T.
Des Moines	861	84	97	29.19	30.13	− .01	30.4	+10.0	55	20	38	2	17	23	33	28	24	77	0.59	− 0.6	5	5,654	sw.	29	sw.	19	6	9	16	6.5	4.3	T.
Dubuque	698	81	96	29.39	30.17	+ .05	28.5	+10.2	54	21	35	0	17	22	24	25	22	80	0.18	− 1.3	3	5,111	nw.	31	nw.	16	7	12	12	5.8	3.0	1.0
Keokuk	614	64	78	29.47	30.18	+ .04	33.9	+10.2	62	20	41	3	17	27	23	30	24	70	1.92	+ 0.2	6	5,621	w.	26	w.	1	5	11	15	6.5	7.6	0.0
Cairo	356	87	93	29.80	30.20	+ .04	41.6	+ 6.8	67	21	49	21	15	34	24	37	32	72	2.27	− 1.6	11	7,687	s.	33	w.	1	4	7	20	7.7	4.5	0.0
Peoria	609	11	45	29.48	30.17	+ .05	32.2	+ 9.1	53	21	39	6	17	25	23	29	26	83	1.39	− 0.8	8	5,660	s.	23	w.	1	12	7	12	5.4	3.2	T.
Springfield, Ill.	644	10	91	29.46	30.16	+ .03	34.4	+ 8.1	60	21	41	7	17	28	21	31	27	79	1.68	− 0.6	10	6,930	s.	27	nw.	16	7	11	13	6.5	3.6	T.
Hannibal	534	74	109	29.57	30.16	+ .03	35.6	+ 8.9	62	20	43	5	17	28	25	....	....	....	1.48	− 0.7	9	6,983	sw.	32	sw.	1	9	7	15	6.4	6.5	0.0
St. Louis	567	265	303	29.54	30.17	+ .03	39.2	+ 8.2	67	21	46	12	17	32	24	34	28	67	1.10	− 1.2	8	10,816	s.	44	s.	6	6	11	14	6.0	2.2	0.0
Missouri Valley.							32.6	+11.6										78	0.86	− 0.1										6.2		
Columbia, Mo.	781	11	84	29.29	30.15	+ .02	36.8	+ 9.6	63	6	45	7	17	28	29	....	....	....	1.54	− 0.7	7	6,333	s.	33	sw.	1	7	7	17	6.9	8.4	0.0
Kansas City	963	161	181	29.09	30.16	+ .01	37.3	+11.1	63	6	44	11	17	30	27	33	28	72	1.48	+ 0.4	6	9,094	sw.	42	nw.	14	8	11	12	6.1	4.8	T.
St. Joseph	967	11	49	29.07	30.14	......	34.4	......	61	20	42	8	17	27	28	31	27	75	0.72	......	5	6,142	sw.	36	nw.	14	6	13	12	6.1	3.5	0.0
Springfield, Mo.	1,324	98	104	28.72	30.16	+ .02	39.8	+ 8.5	68	21	48	15	15	32	30	35	31	77	1.39	− 1.3	6	8,667	s.	30	w.	7	9	9	13	6.1	4.6	0.0
Iola	984	11	50	......	30.14	.00	38.4	+10.8	66	21	47	15	15	30	29	....	....	....	1.77	+ 0.8	7	5,730	s.	25	s.	19	5	6	20	....	9.5	0.0
Topeka	987	92	107	......	......	......	36.6	+11.0	64	20	44	15	17	29	27	....	....	....	1.55	+ 0.6	6	7,771	n.	38	e.	24	5	11	15	6.7	3.2	T.
Drexel	1,299	10	53	28.69	30.13	......	29.4	......	58	19	37	4	12	22	31	27	25	86	0.32	......	6	8,625	sw.	40	e.	24	7	7	17	6.7	2.7	T.
Lincoln	1,189	11	84	28.81	30.12	− .03	32.7	+11.5	62	19	40	10	12	25	37	29	26	81	0.31	− 0.3	4	7,150	sw.	31	nw.	1	8	7	16	6.7	1.2	T.
Omaha	1,105	115	122	28.92	30.15	.00	32.0	+11.5	58	20	39	7	17	25	30	28	24	76	0.48	− 0.2	5	6,078	nw.	33	nw.	14	6	11	14	6.6	5.2	T.
Valentine	2,598	47	54	27.30	30.11	− .01	23.0	+10.8	57	19	39	− 1	25	19	33	25	21	75	0.40	− 0.1	6	7,678	w.	38	w.	19	10	15	6	4.9	5.6	T.
Sioux City	1,135	94	164	28.88	30.14	− .01	28.5	+12.9	59	19	35	5	12	22	35	25	22	79	0.43	− 0.1	4	7,946	s.	53	nw.	16	8	8	15	6.5	4.0	0.3
Huron	1,306	50	74	28.68	30.14	− .02	23.9	+14.4	60	19	33	− 2	12	15	35	20	17	80	0.34	− 0.2	7	7,430	nw.	40	nw.	16	9	7	15	5.7	2.3	1.2
Pierre	1,572	70	75	28.38	30.11	− .02	27.9	+14.0	61	19	38	− 1	12	18	39	24	20	78	0.21	− 0.2	7	6,929	nw.	50	w.	19	13	5	13	5.1	2.5	0.7
Yankton	1,233	49	57	28.76	30.12	− .04	28.2	+12.7	63	19	36	4	12	20	36	....	....	....	0.46	− 0.1	5	6,276	nw.	30	nw.	16	6	8	17	6.7	4.6	1.0

TABLE I.—*Climatological data for Weather Bureau Station, January, 1921*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max.+mean min.÷2.	Temperature of the air: Departure from normal.	Temperature of the air: Maximum.	Temperature of the air: Date.	Temperature of the air: Mean maximum.	Temperature of the air: Minimum.	Temperature of the air: Date.	Temperature of the air: Mean minimum.	Temperature of the air: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with 0.01 inch or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								1–10	In.	In.
Northern Slope.							26.6	+ 7.0										68	0.81	− 0.1										5.2		
Billings	3,140	5	....	......	......	......	29.9	......	61	5	43	6	10	17	44	....	....	....	0.08	......	1	......	sw.	....	......	....	15	16	0	....	1.0	0.0
Havre	2,505	11	44	27.27	29.98	− .12	26.0	+12.5	56	5	37	− 2	16	15	39	22	19	80	0.12	− 0.6	3	6,645	sw.	36	sw.	15	8	18	5	4.8	1.2	0.0
Helena	4,110	87	112	25.72	30.02	− .13	30.0	+10.0	52	18	38	6	11	22	30	23	19	64	0.36	− 0.6	5	5,798	sw.	64	sw.	14	4	9	18	7.0	2.5	0.0
Kalispell	2,973	48	56	......	30.01	− .11	26.1	+ 6.5	48	14	33	6	11	19	26	....	....	....	1.29	− 0.3	15	3,482	nw.	30	sw.	14	3	10	18	....	10.7	3.0
Miles City	2,371	26	48	......	......	......	......	......	....	....	....	....	....	....	....	....	....	....	......	......	....	......	......	....	......	....	....	....	....	....	....	....
Rapid City	3,259	50	58	26.58	30.11	+ .01	30.9	+ 9.4	62	19	42	2	12	20	52	24	16	58	0.78	+ 0.3	5	5,981	w.	39	nw.	15	13	7	11	5.2	7.9	2.8
Cheyenne	6,088	84	101	23.95	30.11	+ .06	28.2	+ 2.6	57	5	39	− 4	11	18	36	23	17	65	1.47	+ 1.1	6	12,079	w.	72	w.	15	13	14	4	4.3	18.4	4.0
Lander	5,372	60	68	24.61	30.18	+ .06	20.8	+ 3.4	52	15	33	−18	12	9	37	16	8	60	0.28	− 0.2	2	3,897	sw.	44	w.	5	17	11	3	3.8	3.0	1.8
Sheridan	3,790	10	47	25.05	30.07	......	27.5	......	61	5	40	− 5	7	15	53	23	16	67	0.54	......	7	3,909	s.	44	w.	15	18	6	7	3.9	6.7	0.8
Yellowstone Park	6,200	11	48	23.82	30.15	+ .01	20.6	+ 3.0	42	25	29	−15	11	12	36	18	14	74	1.49	− 0.8	18	7,208	s.	42	sw.	5	5	8	18	7.3	14.6	10.5
North Platte	2,821	11	51	27.13	30.16	+ .04	30.1	+ 8.7	58	19	41	4	26	19	32	25	20	72	0.68	+ 0.2	3	5,035	w.	30	nw.	13	10	7	14	5.7	3.5	1.2
Middle Slope.							37.3	+ 7.8										67	0.90	+ 0.2										6.0		
Denver	5,292	106	113	24.70	30.08	+ .03	33.8	+ 4.7	63	15	44	9	12	24	36	28	18	56	0.77	+ 0.4	5	5,777	s.	44	w.	14	12	13	6	4.5	12.0	1.0
Pueblo	4,685	80	86	25.29	30.08	+ .03	35.4	+ 6.3	68	15	48	3	12	22	45	28	19	54	0.30	0.0	4	5,670	nw.	39	nw.	3	5	15	11	5.8	0.5	0.0
Concordia	1,392	50	58	28.63	30.15	+ .01	36.2	+11.8	65	19	44	16	12	28	39	31	27	76	0.50	− 0.2	4	6,442	s.	40	s.	19	4	8	19	7.5	1.4	0.2
Dodge City	2,509	11	51	27.48	30.16	+ .05	36.4	+ 9.1	71	15	48	12	11	25	44	30	25	72	0.24	− 0.2	4	8,136	nw.	43	w.	24	10	7	14	5.8	0.1	0.0
Wichita	1,358	139	158	28.67	30.14	+ .01	39.1	+ 9.4	63	20	46	22	13	32	28	35	31	75	1.30	+ 0.5	4	10,043	s.	43	sw.	19	6	11	14	6.5	2.4	0.0
Altus	1,410	5	....	......	......	......	45.6	......	77	6	57	19	9	34	47	....	....	....	0.76	......	4	......	se.	....	......	....	14	2	15	....	2.8	0.0
Broken Arrow	765	11	52	......	......	......	......	......	....	....	....	....	....	....	....	....	....	....	......	......	....	......	......	....	......	....	....	....	....	....	....	....
Muskogee	652	4	....	......	......	......	45.1	......	72	20	54	22	14	36	37	....	....	....	1.38	......	8	......	e.	....	......	....	15	7	9	....	0.3	0.0
Oklahoma City	1,214	10	47	28.85	30.16	+ .05	43.0	+ 5.6	68	6	52	20	13	34	32	38	32	70	2.29	+ 1.0	7	9,820	s.	37	s.	20	7	15	9	5.7	5.1	0.0
Southern Slope.							47.7	+ 6.2										59	0.78	+ 0.1										4.7		
Abilene	1,738	10	52	28.31	30.15	+ .06	50.0	+ 7.4	79	4	62	19	13	38	41	40	32	58	0.68	− 0.2	3	8,118	s.	38	s.	20	14	6	11	5.1	2.8	0.0
Amarillo	3,676	10	49	26.32	30.13	+ .07	41.0	+ 7.1	72	15	53	13	13	29	40	34	28	68	2.10	+ 1.5	6	8,500	sw.	35	nw.	13	19	7	5	3.8	3.2	0.0
Del Rio	944	64	71	29.14	30.14	+ .08	56.5	+ 6.3	83	5	69	27	13	44	47	....	....	....	0.18	− 0.6	3	6,752	se.	32	nw.	14	13	8	10	5.3	0.0	0.0
Roswell	3,566	75	85	26.44	30.11	+ .07	43.2	+ 4.0	74	4	57	11	9	29	45	34	23	50	0.17	− 0.4	4	5,784	s.	42	nw.	8	13	10	8	4.6	1.5	0.0
Southern Plateau.							42.2	+ 1.4										53	0.56	− 0.1										4.2		
El Paso	3,762	110	133	26.27	30.08	+ .07	48.6	+ 4.5	77	18	61	21	9	36	37	37	21	35	0.06	− 0.4	1	7,502	nw.	44	w.	28	15	12	4	3.7	0.4	0.0
Santa Fe	7,013	57	66	23.26	30.13	+ .09	32.4	+ 3.9	55	18	42	9	13	23	32	27	21	67	1.35	+ 0.8	5	5,594	n.	35	n.	14	8	13	10	5.6	8.2	0.0
Flagstaff	6,908	10	59	23.35	30.08	+ .03	28.8	+ 2.1	58	5	43	− 5	24	15	44	24	....	....	1.33	......	5	......	w.	46	s.	18	19	8	4	....	14.0	T.
Phoenix	1,108	76	81	28.91	30.09	+ .06	52.0	+ 2.0	77	16	66	27	12	38	43	41	30	51	0.13	− 1.0	3	3,315	e.	36	w.	18	14	9	8	4.5	0.0	0.0
Yuma	141	9	54	29.96	30.11	+ .03	52.8	− 1.9	74	6	65	28	12	40	34	44	34	54	0.70	+ 0.3	3	3,661	n.	24	w.	10	23	6	2	2.3	0.0	0.0
Independence	3,957	9	41	26.02	30.13	+ .06	38.6	− 1.9	65	5	50	18	12	28	43	32	22	56	0.56	− 0.4	5	4,743	nw.	29	n.	6	12	9	10	5.1	4.9	0.0
Middle Plateau.							32.6	+ 4.1										67	0.74	− 0.3										5.7		
Reno	4,532	74	81	25.46	30.09	− .04	34.8	+ 2.4	63	15	45	10	11	24	40	30	24	66	0.84	− 1.1	9	5,637	w.	48	sw.	5	12	7	12	5.2	4.4	0.4
Tonopah	6,090	12	20	24.08	30.15	......	31.2	......	51	3	38	7	11	24	22	27	21	66	0.22	− 0.5	4	8,585	se.	38	se.	17	8	8	15	5.7	3.5	0.0
Winnemucca	4,344	18	56	25.63	30.11	− .05	32.6	+ 3.8	60	17	42	8	11	23	30	29	23	70	0.46	− 0.6	8	6,385	sw.	43	sw.	5	8	3	20	7.0	4.4	0.1
Modena	5,479	10	43	24.64	30.12	+ .02	28.7	+ 1.2	58	15	41	− 2	12	16	39	24	18	67	1.27	+ 0.5	10	6,766	w.	43	sw.	6	9	18	4	4.7	6.3	T.
Salt Lake City	4,360	163	203	25.67	30.13	− .03	35.7	+ 6.9	58	5	42	16	12	29	24	31	24	64	1.44	+ 0.1	12	5,600	s.	31	sw.	18	8	6	17	6.5	5.9	0.5
Grand Junction	4,602	60	68	25.46	30.14	+ .08	31.0	+ 6.3	58	18	41	5	1	21	31	26	21	70	0.21	− 0.3	3	3,383	se.	30	s.	18	11	10	10	5.3	T.	0.0
Northern Plateau.							33.4	+ 4.5										75	1.72	0.0										7.4		
Baker	3,471	48	53	26.44	30.10	− .06	28.5	+ 4.1	48	5	36	5	23	21	23	26	23	77	2.21	+ 0.9	18	4,928	se.	29	s.	4	7	5	19	6.5	14.2	1.8
Boise	2,739	78	86	27.21	30.13	− .06	34.8	+ 5.5	56	17	42	14	11	27	23	32	28	75	1.57	− 0.3	17	4,876	se.	32	se.	17	6	8	17	7.1	6.9	0.2
Lewiston	757	40	48	29.22	30.05	− .11	37.1	+ 2.6	57	2	44	18	11	31	22	....	....	....	1.20	− 0.4	11	2,889	e.	25	nw.	5	4	4	23	7.9	1.2	0.0
Pocatello	4,477	60	68	25.50	30.14	− .06	29.8	+ 4.7	51	15	36	− 2	22	23	25	27	22	71	0.95	− 0.3	12	9,077	s.	50	s.	18	4	7	20	7.6	8.7	0.8
Spokane	1,929	101	110	27.94	30.04	− .08	32.4	+ 5.7	51	5	38	11	11	26	20	30	27	80	2.55	+ 0.2	21	5,959	sw.	38	sw.	14	2	10	19	7.6	11.1	T.
Walla Walla	991	57	65	28.97	30.06	− .09	37.8	+ 4.6	62	4	44	18	11	32	26	34	30	74	1.87	− 0.1	16	4,696	s.	37	se.	29	4	5	22	7.9	3.3	0.0
North Pacific Coast Region.							41.3	+ 1.4										84	8.33	+ 1.6										8.4		
North Head	211	11	56	29.73	29.96	− .09	41.8	0.0	52	26	46	32	8	38	15	40	37	82	10.65	+ 4.0	29		e.	(a)	se.	29	2	3	26	8.5	T.	0.0
Port Angeles	29	8	53	29.90	29.93	......	38.5	......	55	14	43	27	11	34	17	....	....	....	6.08	+ 0.6	23	4,163	s.	38	se.	29	2	1	28	8.8	1.7	0.0
Seattle	125	215	250	29.85	29.98	− .07	40.4	+ 1.1	52	29	45	27	10	36	13	38	35	82	5.56	+ 1.0	22	9,331	s.	59	s.	29	0	5	26	8.8	3.1	0.0
Tacoma	213	113	120	29.76	30.00	− .04	40.3	+ 2.2	52	29	46	23	11	35	16	40	38	90	6.02	+ 0.2	24	5,807	sw.	38	sw.	29	0	8	23	8.4	2.5	0.0
Tatoosh Island	86	7	57	29.79	29.88	− .10	41.9	+ 0.7	48	1	45	34	16	39	12	40	37	85	18.07	+ 5.9	27	17,325	e.	110	sw.	29	2	4	25	8.5	T.	0.0
Yakima	1,071	4	....	......	......	......	30.6	......	54	14	39	9	6	22	30	....	....	....	1.52	......	11	......	ne.	....	......	....	6	13	12	....	15.1	2.0
Medford	1,425	4	....	......	......	......	39.1	......	59	4	46	19	10	32	25	....	....	....	3.12	......	15	......	se.	....	......	....	2	5	24	....	1.5	0.0
Portland, Oreg.	153	68	106	29.87	30.03	− .05	41.6	+ 3.5	57	4	46	27	11	37	18	39	35	80	7.82	+ 1.3	25	6,012	sw.	29	sw.	29	2	6	23	8.5	0.7	0.0
Roseburg	510	9	57	29.51	30.07	− .03	42.0	+ 1.2	61	25	49	25	11	35	25	40	37	84	4.12	− 1.6	20	2,562	s.	28	w.	5	0	18	13	7.2	0.0	0.0
Middle Pacific Coast Region.							46.2	− 1.1										82	6.02	+ 1.3										6.2		
Eureka	62	73	89	30.04	30.11	+ .01	45.6	− 1.3	58	26	52	29	10	40	24	45	43	89	8.37	+ 0.7	21	5,957	se.	43	n.	9	5	8	18	7.2	0.0	0.0
Mount Tamalpais	2,375	11	18	27.61	30.12	+ .01	41.8	− 4.1	57	15	46	31	21	38	17	....	....	....	4.78	− 1.2	16	17,602	nw.	70	n.	10	7	6	18	6.8	0.5	0.0
Point Reyes Light	490	7	18	29.55	30.07	......	48.8	− 0.6	60	14	52	37	6	45	15	....	....	....	4.39	......	17	17,923	s.	86	s.	29	10	9	12	5.7	0.0	0.0
Red Bluff	332	50	56	29.76	30.12	.00	44.2	− 1.2	58	22	50	32	11	38	20	41	37	77	7.33	+ 3.4	17	6,290	nw.	43	n.	9	10	6	15	5.9	0.0	0.0
Sacramento	69	106	117	30.06	30.13	+ .01	46.2	+ 0.6	57	1	52	30	11	40	20	45	44	91	4.61	+ 0.9	12	6,915	se.	44	se.	30	12	7	12	5.3	0.0	0.0
San Francisco	155	208	243	29.95	30.12	+ .01	49.5	0.0	61	4	54	39	8	44	16	45	40	73	6.30	+ 2.0	13	7,369	se.	51	n.	9	11	3	17	6.1	0.0	0.0
San Jose	141	12	110	30.00	30.14	......	47.2	− 1.1	66	4	56	29	11	33	27	....	....	....	4.75	+ 1.9	11	5,645	se.	35	se.	30	12	2	17	6.3	0.0	0.0
South Pacific Coast Region.							50.9	− 0.2										73	3.51	+ 0.7										5.1		
Fresno	327	89	98	29.79	30.16	+ .06	46.4	+ 1.0	67	5	54	30	11	39	26	43	39	77	2.63	+ 1.0	10	4,269	se.	30	nw.	5	10	6	15	5.8	0.0	0.0
Los Angeles	338	159	191	29.76	30.13	+ .05	54.1	− 0.2	79	15	63	38	11	46	29	48	43	73	3.22	+ 0.4	11	4,442	e.	28	e.	17	13	6	12	4.6	0.0	0.0
San Diego	87	62	70	30.02	30.12	+ .04	53.6	− 0.4	76	15	61	38	12	46	26	48	44	76	2.02	0.0	10	4,049	nw.	38	s.	18	11	9	11	5.0	0.0	0.0
San Luis Obispo	201	32	40	29.92	30.14	+ .05	49.6	− 1.4	76	14	59	26	11	40	37	44	37	66	6.18	+ 1.5	9	3,667	n.	24	s.	17	13	9	9	4.9	0.0	0.0
West Indies.																																
San Juan, P. R.	82	8	54	29.96	30.05	......	74.8	......	85	28	80	65	25	70	16	....	....	....	7.03	+ 2.4	23	10,460	e.	54	ne.	21	8	16	7	5.3	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.74	29.86	.00	79.8	− 0.3	91	25	88	68	17	72	19	72	71	79	0.88	− 0.1	7	7,120	nw.	27	n.	15	10	18	3	4.8	0.0	0.0
Colon	36	7	97	29.84	29.87	− .01	81.1	+ 1.2	87	24	86	72	17	77	12	75	72	77	1.31	− 2.4	19	12,002	n.	29	ne.	8	4	23	4	5.6	0.0	0.0
Alaska.																																
Juneau	80	11	49	......	......	......	24.5	......	41	10	28	10	17	21	21	22	18	76	4.13	......	17	4,475	ne.	25	s.	10	6	7	18	7.0	19.4	18.6

[a] Wind instruments destroyed before highest velocity of wind was reached. Highest velocity recorded, 126 miles; estimated maximum velocity, 150 miles.

TABLE II.*—*Data furnished by the Canadian Meteorological Service, January, 1921.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.50	29.64	−0.22	20.6	− 3.2	26.5	14.8	46	− 1	3.51	−2.40	24.0
Sydney, C. B. I.	48	29.90	29.94	+ .01	22.0	+ 1.5	29.1	15.0	47	− 6	3.97	−1.13	27.5
Halifax, N. S.	88	29.87	29.98	+ .01	24.2	+ 2.4	32.7	15.6	48	− 3	4.05	−1.72	24.2
Yarmouth, N. S.	65	29.93	30.00	.00	27.2	+ 0.9	34.4	19.9	49	5	2.81	−2.60	14.5
Charlottetown, P. E. I.	38	29.90	29.94	− .02	18.6	+ 1.6	26.4	10.9	44	−10	3.42	−0.54	23.9
Chatham, N. B.	28	29.96	30.00	+ .03	14.8	+ 5.0	25.7	4.0	48	−20	2.63	−0.96	18.8
Father Point, Que.	20	30.00	30.03	+ .05	10.3	+ 2.3	19.3	1.3	36	−13	2.54	−0.31	21.5
Quebec, Que.	296	29.72	30.06	+ .04	13.7	+ 4.6	21.3	6.2	38	−16	2.18	−1.83	15.9
Montreal, Que.	187	29.87	30.09	+ .09	17.5	+ 5.8	24.4	10.7	41	−14	1.74	−1.99	12.6
Stonecliffe, Ont.	489	29.46	30.10	+ .08	10.0	+ 3.6	22.8	− 2.7	44	− 3	0.67	−1.65	6.7
Ottawa, Ont.	236	29.84	30.13	+ .10	17.2	+ 7.6	26.4	8.1	44	−23	1.83	−1.16	14.3
Kingston, Ont.	285	29.79	30.12	+ .07	24.6	+ 7.5	32.1	17.1	43	−14	0.54	−2.91	2.8
Toronto, Ont.	379	29.70	30.13	+ .08	27.8	+ 6.4	35.4	20.2	53	− 5	0.67	−2.25	4.0
Cochrane, Ont.	930												
White River, Ont.	1,244	28.66	30.04	+ .03	7.9	+ 8.3	21.3	− 5.4	39	−43	0.90	−0.79	8.0
Port Stanley, Ont.	592												
Southampton, Ont.	656	29.36	30.02	− .01	25.2	+ 4.8	32.0	18.4	46	00	1.97	−2.08	14.5
Parry Sound, Ont.	688	29.38	30.09	+ .08	21.0	+ 7.2	30.7	11.4	44	−28	2.41	−1.67	16.5
Port Arthur, Ont.	644	29.35	30.09	+ .09	15.2	+12.1	24.8	5.7	40	−20	0.64	−0.18	6.4
Winnipeg, Man.	760	29.20	30.08	− .03	7.1	+ 0.3	16.5	− 2.2	33	−33	1.15	+0.27	11.0
Minnedosa, Man.	1,690	28.14	30.06	− .04	5.9	+13.1	15.1	− 3.3	33	−33	0.68	−0.12	6.8
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.64	29.96	− .12	10.7	+14.2	19.6	1.8	38	−26	0.36	−0.14	3.4
Medicine Hat, Alb.	2,144	27.53	29.86	− .21	20.8	+15.3	32.5	9.2	46	−10	0.09	−0.48	0.9
Moose Jaw, Sask.	1,759												
Swift Current, Sask.	2,392	27.30	30.03	− .06	17.7	+14.6	28.9	6.6	49	−15	0.13	−0.51	1.3
Calgary, Alb.	3,428	26.22	29.92	− .11	17.4	+ 9.0	29.5	5.4	47	−16	0.89	+0.36	8.9
Banff, Alb.	4,521	25.17	29.91	− .09	17.8	+ 5.7	26.4	9.2	34	−13	2.78	+1.59	27.8
Edmonton, Alb.	2,150	27.50	29.91	− .12	9.1	+ 7.3	19.3	− 1.1	41	−33	0.79	+0.11	7.9
Prince Albert, Sask.	1,450	28.36	30.02	− .07	5.1	+13.5	14.1	− 3.8	30	−36	1.08	+0.11	10.8
Battleford, Sask.	1,592	28.15	29.98	− .10	7.6	+13.5	17.1	− 1.9	37	−25	0.83	+0.40	8.0
Kamloops, B. C.	1,262	28.68	29.93	− .03	26.9	+ 1.9	33.3	20.5	47	7	0.65	−0.17	6.5
Victoria, B. C.	230	29.67	29.93	− .04	40.2	+ 1.7	43.9	36.4	52	29	5.55	+0.16	2.4
Barkerville, B. C.	4,180	25.40	29.57	− .32	18.8	+ 1.0	25.4	12.2	34	− 4	4.80	+2.20	48.0
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151	30.00	30.17	+ .04	61.9	−0.1	67.5	56.4	73	46	5.99	+1.05	0.0

*Heretofore known as Table III. Table II, formerly "Details of excessive precipitation," is no longer published in the REVIEW, but appears in the Annual Report of the Chief of the Weather Bureau. See "Description of Tables and Charts," p. 41.

SEISMOLOGY.

SEISMOLOGICAL ABBREVIATIONS USED IN THE INSTRUMENTAL REPORTS.

CHARACTER OF THE EARTHQUAKE.

I=noticeable.
II=conspicuous.
III=strong.
d=(terræ motus domesticus)=local earthquake (sensible or felt).
v=(terræ motus vicinus)=near-by earthquake (within 1,000 km.).
r=(terræ motus remotus)=distant earthquake (1,000 to 5,000 km. distant).
u=(terræ motus ultimus)=very distant earthquake (beyond 5,000 km.).
$\triangle$=distance to epicenter.

PHASES.

P=(undæ primæ)=first preliminary tremors.
PR_n=P waves reflected *n* times at the earth's surface.
S=(undæ secundæ)=second preliminary tremors.
SR_n=S waves reflected *n* times at the earth's surface.
PS=transformed waves; longitudinal (P) to transversal (S) or vice versa.
L=(undæ longæ)=long waves in the principal portion.
M=(undæ maximæ)=greatest motion in the principal portion.
C=(coda)=trailers.
O=time at epicenter.
L_{rep1}=long waves reaching the station from the antiepicenter (40,000 km.$-\triangle$).
L_{rep2}=long waves again reaching the station from the antiepicenter (40,000 km.$+\triangle$).
F=(finis)=end of perceptible trace.

NATURE OF THE MOTION.

i=(impetus)=abrupt beginning.
e=(emersio)=gradual appearance.
T=(period)=twice time of oscillation.
A=amplitude of earth's movement, reckoned from the zero line. E, N, or Z attached to a symbol signifies the E-W, the N-S, or the vertical component, respectively, thus:
P_E is the E-W component of P.
P_N is the N-S component of P.
P_Z is the vertical component of P.
μ=micron, $\frac{1}{1000}$ mm.

INSTRUMENTAL CONSTANTS.

T_0=period of instrument.
V=magnification of instrument.
ε=damping ratio.

List of instrumental stations from which reports are received.

Location.	Latitude, N.	Longitude, W.	Elevation, meters.	Description of instruments.	Instrumental constants. E-W. V	E-W. T_0	E-W. ϵ	N-S. V	N-S. T_0	N-S. ϵ	Institution.	Director.
	° ′ ″	° ′ ″										
ALABAMA.												
Mobile	30 41 44	88 08 46	60	Wiechert 80-kg., astatic, horizontal pendulum.							Spring Hill College, seismic observatory.	Cyril Ruhlman, S. J.
ALASKA.												
Sitka	57 03 00	135 30 03	15.2	Two Bosch-Omori 10 and 12 kg.	10	18		10	18		U. S. Coast and Geodetic Survey, Magnetic Observatory.	F. P. Ulrich.
ARIZONA.												
Tucson	32 14 48	110 50 06	769.6	....do	10	18		10	18		....do	Wm. H. Cullum.
CALIFORNIA.												
Point Loma	32 43 03	117 15 10	91.4	Two-component C.D.West seismoscope.							Theosophical University	F. J. Dick.
COLORADO.												
Denver	30 40 36	104 56 54	1,655	Wiechert 80-kg., astatic, horizontal pendulum.							Sacred Heart College, earthquake station.	A. W. Forstall, S. J.
DISTRICT OF COLUMBIA.												
Washington	38 54 25	77 04 24	42.4	Wiechert 200-kg., astatic, horizontal pendulum; *80-kg. vertical.*	165	5.4	0	143	5.2	0	Georgetown University, department of geology.	F. A. Tondorf, S. J.
					VERTICAL: *V, 80;*	*T^0, 3.0;*	*ε, 0.*					
				Bosch photographic pendulums (horizontal), 200 g.	133	5.0		133	5.0			
				Mainka astatic pendulums, 135-kg.	47	9.0		59	9.0			
				Bosch-Omori, 25-kg								
Do	38 54 12	77 03 03	21	Marvin, vertical pendulum, undamped, mechanical registration.	110	6.4		110	6.4		U. S. Weather Bureau	W. J. Humphreys.
HAWAII.												
Honolulu	21 19 12	158 03 48	15.2	Milne seismograph of the Seismol. Comm. Brit. Assoc.		18	[1]0″.48				U. S. Coast and Geodetic Survey, Magnetic Observatory.	H. E. McComb.
ILLINOIS.												
Chicago	41 47 00	87 37 00	180.1	Two Milne-Shaw horizontal pendulums, 0.45-kg.	150	12	20:1	150	[2]12	20:1	University of Chicago	H. J. Cox.
MARYLAND.												
Cheltenham	38 44 00	76 50 30	71.6	Two Bosch-Omori 10 and 12 kg.	10	15		10	15		U. S. Coast and Geodetic Survey, Magnetic Observatory.	George Hartnell.
MASSACHUSETTS.												
Cambridge	42 22 36	71 06 59	5.4	Two Bosch-Omori 100-kg., horizontal pendulum, mechanical registration.	80	23	0	50	25	4:1	Harvard University seismographic station.	J. B. Woodworth.
MISSOURI.												
St. Louis	38 38 15	90 13 58.5	160.4	Wiechert 80-kg., astatic, horizontal pendulum.	80	7	5:1				St. Louis University, geophysical observatory.	J. B. Goesse, S. J.
NEW YORK.												
Buffalo	42 53 02	78 52 40	180.5	Wiechert 80-kg., horizontal.	80	7	5:1				Canisius College, department of physics.	E. J. Kolkmeyer.
Ithaca	42 26 58	76 29 09	242.6	Two Bosch-Omori 25-kg., horizontal pendulum, mechanical registration.	13	22	4:1	14	25	4:1	Cornell University, seismograph station.	P. S. Sheldon.
New York	40 51 47	73 53 08	23.9	Wiechert 80-kg	72	5.6	0	72	3.5	0	Fordham University	Jos. Lynch, S. J.
CANAL ZONE.												
Balboa Heights	8 57 39	79 33 29	27.6	Two Bosch-Omori 100-kg. and 25-kg.	{35, 10}	}20		{35, 10}	}20		Panama Canal, Department Operation and Maintenance, section of meteorology and hydrography.	Governor, Panama Canal.
PORTO RICO.												
Vieques	18 09 00	65 27 00	19.8	Two Bosch-Omori	10	17		10	19		U. S. Coast and Geodetic Survey, Magnetic Observatory.	W. M. Hill.
VERMONT.												
Northfield	44 10 00	72 41 00	256	Two Bosch-Omori mechanical registration.	10	15		10	16		U. S. Weather Bureau	Wm. A. Shaw.
CANADA.												
Ottawa	45 23 38	75 42 57	83	Two Bosch photographic horizontal pendulum, one Spindler & Hoyer 80-kg. vertical seismograph.	120	26					Dominion Observatory, earthquake station.	E. A. Hodgson.
Toronto	43 40 01	79 23 54	113.7	Milne horizontal pendulum, North, in the meridian.		18	[1]0″.45				Dominion Meteorological Service.	
Victoria	48 24 00	123 19 00	6.7	Wiechert, vertical; Milne horizontal pendulum, North, in meridian.		18	[1]0″.54				....do	

[1] Sensitivity.

[2] From Jan. 31, 1921.

For the reports of the stations at the University of California, Berkeley, Calif., and at the Lick Observatory, Mount Hamilton, Calif., see *Bulletin of the Seismographic Stations, University of California;* for the report of the station at the University of Santa Clara, Santa Clara, Calif., see *Record of the Seismographic Station, University of Santa Clara.*

SEISMOLOGICAL REPORTS FOR JANUARY, 1921.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, D. C., March 3, 1921.]

TABLE 1.—*Noninstrumental earthquake reports, January, 1921.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
1921.	*H. m.*	CALIFORNIA.	° ′	° ′			*Sec.*			
Jan. 13	10 30	Willows	34 03	118 15	5	1	3	None	Felt by many	J. T. McPherson.
14	12 00	Lone Pine	36 37	118 01	4	1		...do	Felt by several	G. F. Marsh.
	13 00	Lone Pine	36 37	118 01	4	1		...do	...do	Do.
	13 50	Lone Pine	36 37	118 01	5	1		...do	Felt by many	Do.
20	19 46	Calexico	32 41	115 30	4	1	4	Rumbling	...do	W. S. Pratt.
25	2 15	Aguanga	33 30	117 00	2	1	2	Loud	Felt by two	A. J. Berg.
25	21 24	Calexico	32 41	115 30	3	5	1	Faint	Felt by many	W. S. Pratt.
		KENTUCKY.								
9	21 49	Hickman	36 34	89 12	2	1	3	None	Felt by several	R. B. Coffee.
		MISSOURI.								
9	21 40	New Madrid	36 35	89 32		1	Few.	...do	Felt by many	Miss J. G. Smith.
		NEW JERSEY.								
26	23 40	Atsion	39 45	74 45		1		Rumbling	Similar to explosion	I. M. Armstrong.
	23 45	Burlington	40 05	74 50		1		...do	Felt by many	D. S. B. McCoy.
		Harlem Heights			4	1	60	...do	...do	G. N. Abel.
	23 40	Moorestown	75 00	39 55	4-5		10-20	...do	...do	F. E. Stokes.
		Palmyra	75 00	40 00	4	2	3-5	None	Felt by several	A. L. Urban, jr.
		Riverside	74 56	40 05	5	2	1	Rumbling	Felt by many	A. Thielmann.
		Riverton	75 00	40 00	5	1	30	...do	...do	R. E. Mattis.
		Riverton	75 00	40 00	4-5	1	5	...do	...do	G. T. Dold.
		TENNESSEE.								
9	20 30 *ca.*	Tiptonville	36 24	89 30	4	1	60	None	...do	Lucille M. Stanley.

LATE REPORTS.

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
1920. Dec. 17	9 55	Brigham, *Utah*	41 30	112 00	4	1		Rumbling	Felt by several	J. N. Anderson.
	10 05	Brigham, *Utah*	41 30	112 00	4	1		...do	...do	Do.
29	9 50	Willows, *Calif.*	34 03	118 15	5	2	3 *ca.*	...do	Felt to east and north also	F. J. McPherson.

TABLE 2.—*Instrumental seismological reports, January, 1921.*

[Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.]

CALIFORNIA. *Theosophical University, Point Loma.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1921.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Jan. 8					200	200		Tremors.
9					100	100		
16					100	100		
20					100	100		
30					200	200		

DISTRICT OF COLUMBIA. *Georgetown University, Washington.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1921.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Jan. 2		e_E	7 29 43					Not discernible on NS.
		F	7 45 —					
8		eP_E	6 40 46					Heavy micros; S_N very doubtful.
		eP_N	6 40 46					
		eS_E	6 46 44					
		eS_N?	6 46 17					
		eL_E	6 50 24	6				
		eL_N	6 50 24	6				
		F	7 10 —					
9		eP_E	13 04 21					Sheets off at 13h. 44m.; quake still on; heavy micros.
		eP_N	13 04 17					
		S_E	13 11 42					
		S_N	13 11 41					
		eL_E	13 18 24					
15		e_N	15 20 13					Heavy micros.
		F	15 35 —					
20		eP_E?	21 10 44					
		eP_N?	21 10 42					
		L_E	21 20 18	22				
		L_N	21 21 42	21				
		F	21 30 —					

DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1921.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Jan. 2		e	7 29 40					
		F	7 34 —					
8		P	6 41 42				3,400	L not defined.
		S	6 46 54					
		F	7 00 *ca.*					
9		P	13 04 16					
		S						Lost in changing sheets.
		F	13 35 *ca.*					L not discernible.
20		P	21 08 09				3,500	
		e	21 13 23					
		L	21 20 45					
		F	21 30 *ca.*					

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1921.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Jan. 9		e	13 20 42					
		L	13 36 36	21				
		M	13 43 42		* 200			
		C	13 47 —					
		LR	14 08 —					
		F	15 50 —					
14		L	19 22 00					
		M	19 27 00		* 100			
		C	19 30 —					

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, January, 1921*—Continued.

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu*—Con.

Date	Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921. Jan. 20	e	1 37 48					
	e	1 41 18					
	eL	1 46 30					
	M	1 53 30		*100			
	C	1 56 —					
	F	2 11 —					
20	e	21 24 36					
	L	21 37 42	20				
	M	21 43 42		*500			
	C	21 48 —					
	F	22 18 —					

ILLINOIS. *U. S. Weather Bureau, Chicago.*

Date	Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921. Jan. 6	P?	12 30 10					
	S?	12 40 10					
	L	12 58 30	25				
	L	13 02 —	20				
	L	13 08 —	18				
	F	13 40 ca.					
7	L_E	2 09 00	18				Heavy micros; other phases lost.
	F	2 25 —					
7	eL	4 08 —	18				Do.
	F	5 ca.					
8	P	6 41 36				3,000	
	S	6 46 18					
	L?	6 48 48					
	F	7 15 ca.					
9	P	13 04 40				6,200	
	S	13 12 28					
	L	13 22 20					
	L	13 22 49	15				
	F						Merged in succeeding quake.
9	P	14 31 05?					Micros.
	S?	14 39 00					
	eL	14 46 20	18				
	L	14 49 50	18				
	F	15 40 ca.					
20	P	21 11 01				5,200	
	S	21 17 54					
	L?	21 25 40					
	F	22 20 ca.					

NEW YORK. *Fordham University, New York.*

Date	Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921. Jan. 26	e_E	10 52 41					Irregular quavers continue throughout the day.
27	e	12 33 —					Intermittent wavelets similar to those of the 26th, but not so prolonged.

CANAL ZONE. *Panama Canal, Balboa Heights.*

Date	Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921.			100 Kg. instrument.				
Jan. 9	P_E	13 00 12				2,400	
	P_N	13 00 08					Direction NW.
	S_E	13 04 24					
	S_N	13 04 16					
	L_E	13 07 11					
	L_N	13 07 00					
	M_E	13 04 30		*500			
	M_N	13 04 40			*800		
	F_E	13 24 00					
	F_N	13 26 00					
20	P_E	21 03 46				425	Do.
	P_N	21 08 44					
	S_E	21 04 32					
	S_N	21 04 32					
	L_E	21 05 04					
	M_E	21 05 13		*6,000			
	M_N	21 05 52			*6,000		
	F_E	21 20 00					
	F_N	21 24 00					
			25 kg. instrument.				
9	P_N	13 00 13				2,400	Slight on EW.
	S_N	13 04 25					
	L_N	13 06 56					
	M_N	13 04 54			*800		
	F_N	13 23 30					

* Trace amplitude.

CANAL ZONE. *Panama Canal, Balboa Heights*—Continued.

Date	Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921. Jan. 20	P_E	21 03 44				425	
	P_N	21 03 46					
	S_E	21 04 29					
	S_N	21 04 31					
	L_E	21 05 00					
	L_N	21 04 49					
	M_E	21 05 05		*3,500			
	M_N	21 06 02			*3,000		
	F_E	21 19 00					
	F_N	21 19 00					

CANADA. *Dominion Observatory, Ottawa.*

Date	Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921. Jan. 2	e?	7 29 00					Very faintly marked.
	e_E?	7 39 00					
	e_E	7 45 20					Barely discernible.
	eL?	7 51 15					
	F	8 10 ca.					
7	eLE	4 09 30	20				Small amplitude L waves; earlier phases lost entirely in micros.
	L_E	4 31 —	24?				
	L_E	4 38 30	20				
	L_E	4 46 —					
	F						Lost in micros.
8	O	6 35 23				3,910	
	P_N	6 42 35					
	$PR1_N$?	6 43 42					
	$PR2_N$?	6 43 52					
	S	6 48 17					
	eL	6 51 27					
	L	6 53 —					
	F	7 05 ca.					
9	O	12 55 03				6,480	
	P_N	13 05 02					
	PR E	13 07 34					
	PR	13 08 25					
	S	13 13 04					
	$SR2_E$?	13 19 14					
	eL_E	13 23 40	12?				
	L_E	13 31 —	20				
	L_E	13 35 —	16				
	F	13 45 ca.					
9	L_E	14 55 36	20				May possibly be part of preceding quake.
	L_E	15 03 30					
	L_E	15 17 —					
	F	15 20 —					
19	e_E	15 19 11					NS lost in micros.
	L_E	15 44 30	20				
	L_E	15 53 —	16				
	F	16 02 ca.					
20	O	21 06 31				2,000	
	P_{EN}?	21 11 52					
	S_E?	21 16 05					
	eL_E	21 18 40	20				
	L_E	21 22 40	16				
	L_E	21 32 —					
	F	21 50 —					

CANADA. *Dominion Meteorological Service, Victoria.*

Date	Phase	H. m. s.	Sec.	μ	μ	Km.	Remarks
1921. Jan. 1	L	8 22 49					
	M	8 26 16		*200			
	F	8 31 11					
2	P?	7 06 08					
	S	7 13 01					
	L	7 23 21					
	M	7 36 08		*200		5,190	
	F	7 56 17					
3	P?	21 40 21					P may be L phase.
	M	21 44 06		*100			
	F	21 48 31					
6	M	12 48 41		*300			P, S, and L lost when city lights out.
	F	13 21 09					
7	L?	1 24 39					
	M	1 47 16		*200			
7	P?	3 30 04					
	L	3 39 54					
	M	3 58 35		*400			
	F	5 06 58					
9	L	13 16 34					
	M	13 38 19		*500			
	F	14 48 01					
15	L?	13 03 23					
	M	13 07 49		*500			
	F	13 15 11					No further returns since 15th.

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, January, 1921*—Contd.

CANADA. *Dominion Meteorological Service, Toronto.*

1921. Jan.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
1								Isolated micros in early morning.
2		e	7 31 42					
		L	7 55 18					
		L	8 00 42					
		L	8 03 36					
		M	8 04 18		*200			
		F	8 06 54					
3		eL	21 44 21					
		M	21 45 06		*200			
		F	21 47 12					
6		L	13 06 30					
		eL	13 09 42					
		eL	13 15 54					
		M	13 17 12		*300			
		F	14 15 36					
7		L	1 59 24					
		eL	2 06 18					Small micros going on all morning.
		M	2 09 18		*300			
		eL	2 15 36					
		F	2 26 18					
7		L	3 37 30		*100			
7		L	4 11 30					
		M	4 17 06		*300			
		eL	4 20 48					
		eL	4 40 12					
		M	4 42 12		*300			
		eL	4 51 06					
		F	5 03 54					
9		iS	13 13 12					S preceded by micros.
		e	13 20 00					
		eL	13 25 18					
		eL	13 27 30					
		M	13 30 00		*400			
		eL	13 39 24					
		F	13?58 06					
9		eL	14 55 06					Micros 14:21:54. 14:35:00.
		M	14 58 24		*500			
		F						Micros.
15		L	13 10 18					Small micros going on.
		F	13 14 54?			*100		
16		S	16 11 30					S may be P phase.
		eL	16 16 18					
		M	16 17 12		*200			
		F	16 20 36					May not be seismic.
19		iL	15 30 36					
		M	15 32 06		*200			
		eL	15 40 54					
		eL	15 51 30					
		F						Micros.
20		P	21 06 12					
		S	21 13 00					
		e	21 18 06					
		eL	21 19 42					
		eL	21 22 12					
		M	21 24 06		*800			
		F	21 52 54					
25		eL	22 55 30					
		eL	22 57 06					
		M	22 58 06		*300			
		F						Do.
26		eL	12 38 18					Heavy micros going on from 11 hrs.
		M	12 38 48		*300			
		F						
31								Heavy micros began at 0h. 52m. 06s., continuing all day.

* Trace amplitude.

No earthquakes were recorded at the following stations during January, 1921:

ALABAMA. *Spring Hill College*, Mobile.
COLORADO. *Sacred Heart College*, Denver.
MISSOURI. *St. Louis University*, St. Louis.
VERMONT. *U. S. Weather Bureau*, Northfield.
MARYLAND. *U. S. C. & G. S. Magnetic Observatory*, Cheltenham.
PORTO RICO. *U. S. C. & G. S. Magnetic Observatory*, Vieques.
ARIZONA. *U. S. C. & G. S. Magnetic Observatory*, Tucson.
ALASKA. *U. S. C. & G. S. Magnetic Observatory*, Sitka.

Reports for January, 1921, have not been received from the following stations:

MASSACHUSETTS. *Harvard University*, Cambridge.
NEW YORK. *Cornell University*, Ithaca.

SEISMOLOGICAL DISPATCHES.

[Collected by seismographic station, Georgetown University, Washington, D. C.

Mendoza, Argentina, January 5, 1921.—The entire region affected by the disastrous earthquake of December 17 was again visited by an unusually strong shock at 3 o'clock, Monday afternoon (January 3). This one, which was of five seconds' duration, was the worst felt since December, and it leveled the few walls left standing in the destroyed towns of La Valle and Castro de Araujo, near Mendoza. Reports state that the shock was felt in Santiago. (A.)

Paris, January 7, 1921.—Dispatches to the Albanian authorities indicate that the recent earthquake disaster in the Elbassan district was for more serious than was shown by the earlier reports. The shocks were especially heavy in the area between Tepelini and Elbassan. The latter city is almost completely razed. (A.)

Los Angeles, January 8, 1921.—The towns of Covina, Glandor, and Azusa, in the San Gabriele Valley, 20 miles east of here, were rocked to-night by what was declared to be a series of explosions, according to reports received here. Every house in the towns were shaken and windows broken. The first shock was felt at about 9:30 and was followed by two more within half an hour. Each was accompanied by a loud report. Otherwise the tremblings resembled an earthquake. (A.)

Willows, Calif., January 13, 1921.—A sharp earthquake, lasting about three seconds, was felt here at an early hour to-day. Sleepers were aroused, but no damaged was reported. A similar shock was felt here on December 29 last. (A.)

Rome, Italy, January 14, 1921.—Two earth tremors occurred last night in Faenza, in north central Italy between Bologna and Ravenna. First tremor was at 7 p. m. and the second at 9:30 p. m. There is no mention of damage in the report. (A.)

Santiago, Chili, January 17, 1921.—A violent earthquake was felt here at 9:30 o'clock this Monday (17th) evening. Hundreds of persons fled to the streets in alarm. No serious damage reported. (A.)

Devonshire Dock, Bermuda, January 18, 1921.—Slight tremors were felt here on January 18 at 16 minutes past 6 o'clock p. m. (S. C.)

Glen Falls, N. Y., January 19, 1921.—The first shocks were felt at Corinth at 5 o'clock a. m., and two hours later they were felt at Lake George. Houses were shaken to the rattling of dishes. (A.)

Glen Falls, N. Y., January 19, 1921.—What are believed by residents to have been earthquake shocks were felt to-day for three minutes at Corinth and Lake George. (A.)

Philadelphia, Pa., January 26.—An earth tremor or an explosion of great violence was felt here about 6:45 o'clock. (A.)

Glen Falls, N. Y., January 27.—Villages throughout this section were shaken this morning, for the third time in less than two weeks, by what is believed to have been an earthquake. The vibrations were reported from Lake George, Hudson Falls, Fort Edward, Greenwich, and other places. (A.)

F. TONDORF, S. J., *Director*.

A.=Associated Press. S. C.=special cable.

TABLE 3.—*Late reports (instrumental).*

MASSACHUSETTS. *Harvard University, Cambridge.*

1920.			*H m. s.*	*Sec.*	μ	μ	*Km.*	
Sept. 4	....	O.....	14 08 30				10,600	95.4° of arc; steady mass jerked W.
		P_E....	14 22 10					
		S......	14 30 29	7				Micros only on N; Me very low; weak.
		e......	14 34 56	6				
		eL_E...	14 55 10	46				LR1 not found.
		L.....	15 06 20	20				
		L_E....	15 33 26	18				
		L_N....	16 34 07	8, 10				Probably of different origin and less distance.
			to 35 07					
		F?....	16 45 *ca.*					
7	....	O.....	5 55 44				6,215	53.9° arc; not clearly shown on EW; offset eastward.
		e_E.....	6 06 22					
		i......	6 06 49					
		S_E.....	6 13 26	8				
		eL_E...	6 23 07	28				L not distinct; earthquake in N. Italy.
		L.....	6 29 00	20				
		F?....	7 09 *ca.*					
8	....	O.....	1 46 17				10,540	94.86° of arc; from eL–S; eL difficult.
		e_E.....	2 04 52					
		i_E.....	2 06 32					
		S_E.....	2 11 07	6				
		eL_E...	2 12 29	6				
		eL....	2 15 16	10				
		L.....	2 16 42	12				
		L.....	2 22 42	24				
		eL_E...	2 32 32	30				
		L.....	2 51 04	23				
		F.....	3 37 *ca.*					
9	....	(O)....	(18 55 36)				13,750	O taken from Riverview 3150; Harvard O from eLe-(O Riverview), at V_L 228 kms./min.; A increases; micros only on N.
		e_E.....	19 15 47					
		e......	19 27 27					
		e......	19 34 18	24				
		eL_E...	19 55 49	30				
		L.....	19 58 01	26				
		L.....	20 01 24	20				
		L.....	20 15 00	16				
		LR1..	20 59 18	20				
		F.....	21 16 *ca.*					
17	....	O.....	23 50 59				2,800	25.2° arc; North Atlantic region?
18	....	S_E.....	0 01 05	10				
		eL_E...	0 03 16	24				
		L.....	0 03 51	20				
		C.....	0 10 00	16				
		C.....	0 15 39	16				
		F.....	0 24 *ca.*					
20	....	O.....	(14 38 36)				(13,780)	N undamped; E damped by magnet; 1½/1 only.
		$PR1_E$.	14 59 14					
		$PR1_N$.	14 59 46					
		i_E.....	15 00 56	14				
		$PR3_E$.	15 05 08	11				
		iS_E....	15 07 56					
		i_E.....	15 11 30	12				
		i_N.....	15 11 43	6				
		$SR1_E$.	15 15 57	20				
		$SR1_N$.	15 16 28	18				
		e_E.....	15 19 02	26				
		$SR2_E$..	15 21 42	18				
		eL_N...	15 33 42	40				
		eL_E...	15 35 47	40				
		M_E....	15 43 00	24				
		eM_N...	15 44 44	26				
		M_N....	15 46 05	20		28.3		
		C_N....	15 46 59	16				
		eM_N...	15 48 42	20				
		M_N....	15 49 26	19				51 mm. trace.
		M_E....	15 49 00	19				5.9 mm. trace. The M_N form a long spindle-shaped group having their middle M at this epoch.
		M_N....	15 50 08			*46,500		
		M_N....	15 50 44			*62,000		
		C_N....	15 54 00					
		eM_N...	15 58 52	18		*3,000		
		eM_N...	16 04 42	18		*2,100		3 waves.
		eM_N...	16 11 04	18				4 waves.
		$?LR1_E$	16 44 *ca.*	24				
		F.....	17 37 —					
21	....	O.....	(2 38 54)				2,700	NSW; O from Riverview.
		e?.....	3 52 17	12				Faintly and poorly registered, on EW only.
		L.....	3 55 36	20				
			to 56 25					
21	....	O.....	(17 42 46)					Not recorded on NS.
		e......	.. .. ..					
		$eL?_E$..	18 27 17	24				
		L.....	18 34 08	20				
		L.....	18 37 50	15				
		F.....	18 50 *ca.*					
24	....	O.....	21 54 03				3,950	35½° of arc.
		Pn_E...	22 02 30	3				
		i_E.....	22 03 35	3				
		$_N$.....	22 03 45	4				
		S_E.....	22 08 04	7				
		Sn....	22 08 10	7				
		eL_E...	22 10 45	26				M 0.5 mm. trace.
		eL_N...	22 10 50	8, 10				
		F.....	23 03 *ca*					

* Trace amplitude.

MASSACHUSETTS. *Harvard Universiby Cambridge.*—Continued.

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Sept. 27	....	O.....	3 *postea.*					Phases indistinct.
		e_N?....	5 37 15					
		e_N.....	5 38 41	6				
		e_E.....	5 44 04	4				
		e_E.....	5 44 39	2				
		e_N.....	5 44 36					
		L_E....	5 45 02	8				
		e_N.....	5 45 07	6				
		L_E....	5 46 01	11				M_E 5 46 01; 3½ mm.
		L_N....	5 47 29	19				
		F_E....	6 30 *ca.*					

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 1	....	e......	14 29 06					
		L.....	14 32 54					
		M.....	14 40 00		*100			
		C.....	14 44 ..					
		F.....	14 59 ..					
3	....	e......	18 31 30					Slight record.
		L.....	18 42 24					
		M.....	18 45 54		*100			
		C.....	18 47 ..					
		F.....	18 52 ..					
5	....	eP....	22 07 42					iP faint; L difficult to place.
		iS.....	22 14 12					
		(?)eL .	22 20 00					
		M.....	22 33 30		*100			
		C.....	22 37 ..					
		F.....	23 54 ..					
7	....	e......	15 31 30					
		L.....	15 39 36					
		M.....	15 46 54		*200			
		C.....	16 00 ..					
		F.....	16 22 ..					
10	....	e......	4 51 00					L certainly present at L_2 and possibly at L_1.
		i......	4 58 42					
		L_1.....	5 07 54					
		L_2.....	5 12 00					
		M.....	5 19 00		*2,700			
		C.....	5 21 36					
		F.....	7 55 ..					
11	....	eP....	21 34 12					eP faint; S and L well marked.
		iS.....	21 42 42					
		L.....	21 52 54					
		M.....	21 58 24		*300			
		C.....	22 05 ..					
		F.....	22 18 ..					
13	....	P.....	3 51 54					P and S well marked.
		iS.....	3 59 36					
		L.....	4 08 30					
		M.....	4 17 42		*1,100			
		C.....	4 21 ..					
		F.....	5 08 ..					
16	....	P.....	12 18 24					P somewhat uncertain on account of other tremors in trace, which also obscure the point F; L idefinite.
		iS.....	12 28 42					
		iSR_1..	12 34 24					
		M.....	13 00 00		*26,000			
		C.....	15 03 ..					
		F.....	15 49 ..					
16	....	e......	21 25 42					
		L.....	21 34 00					
		M.....	21 42 36		*800			
		C.....	21 47 ..					
		F.....	22 24 ..					
17	....	e......	19 25 48					
		e......	19 43 30					
		L.....	19 53 00					
		M.....	19 55 48		*300			
		C.....	20 05 ..					
		F.....	21 11 ..					
18	....	eP....	10 16 48					eP faint; emergence oj S gradual.
		eS.....	10 26 18					
		L.....	10 40 24	22				
		M.....	10 48 54		*400			
		C.....	10 52 ..					
		F.....	11 22 ..					
19	....	eP....	20 22 00					eP faint.
		iS.....	20 28 30					
		eL....	20 36 00	24				
		M.....	20 56 18		*200			
		C.....	21 05 ..					
		F.....	21 50 ..					
25	....	e......	11 45 30					First phase faint second and third have considerable amplitude but emerge slowly.
		e......	12 01 06					
		e......	12 08 00					
		L.....	12 20 00					
		M.....	12 32 36		*600			
		C.....	12 34 ..					
		F.....	12 53 ..					

* Trace amplitude.

TABLE 3.—*Late reports (instrumental).*

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*

Date		Phase	*H. m. s.*	*Sec.*	μ	μ	*Km.*	Remarks
1920. Dec. 10	....	P_E....	4 43 22	9	......	......	......	eP_N and eS_E quite faint; no distinct M on NS.
		eP_N...	4 43 27	......	......	......	......	
		eS_E...	4 49 50	......	......	......	......	
		L_E....	4 57 39	......	......	......	......	
		L_N....	5 00 45	......	......	......	......	
		M_E....	4 58 10	20	15	......	......	
		M_N....	....	......	......	15	......	
		C_E....	5 00 ..	......	......	......	......	
		F_N....	5 17 ..	......	......	......	......	
		F_E....	5 31 ..	......	......	......	......	
11	....	e_E....	21 36 39	......	......	......	......	Slight record.
		L_E....	21 38 35	......	......	......	......	
		F_E....	21 46 ..	......	......	......	......	
1920 Dec. 16	....	e_E.....	12 36 50	......	......	......	......	In both components the first phase is faint and difficult to place.
		e_N.....	12 38 12	......	......	......	......	
		e_E.....	12 43 11	......	......	......	......	
		i_N.....	12 44 10	......	......	......	......	
		e_N.....	12 49 10	......	......	......	......	
		L_E....	12 59 40	......	......	......	......	
		L_N....	13 03 30	35	......	......	......	
		M_E....	13 16 24	22	335	......	......	
		M_N....	13 17 45	22	......	1,165	......	
		C_N....	13 28 ..	·20	......	......	......	
		C_E....	13 33 ..	20	......	......	......	
		F_N....	14 22 ..	16	......	......	......	
		F_E....	14 32 ..	16	......	......	......	

Chart I. Hydrographs of Several Principal Rivers, January, 1921.

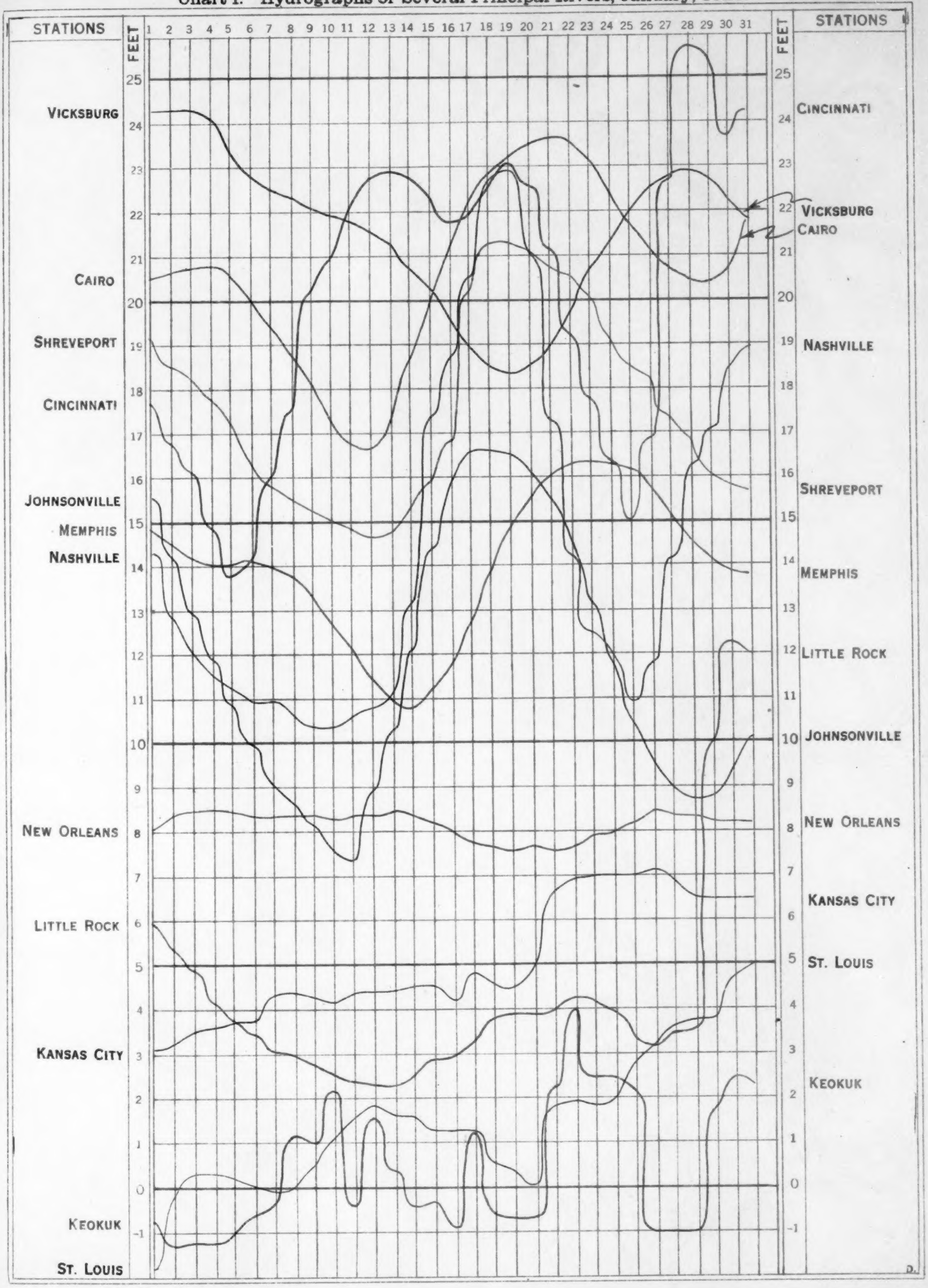


Chart II. Tracks of Centers of High Areas, January, 1921.
(Plotted by Wilfred P. Day.)

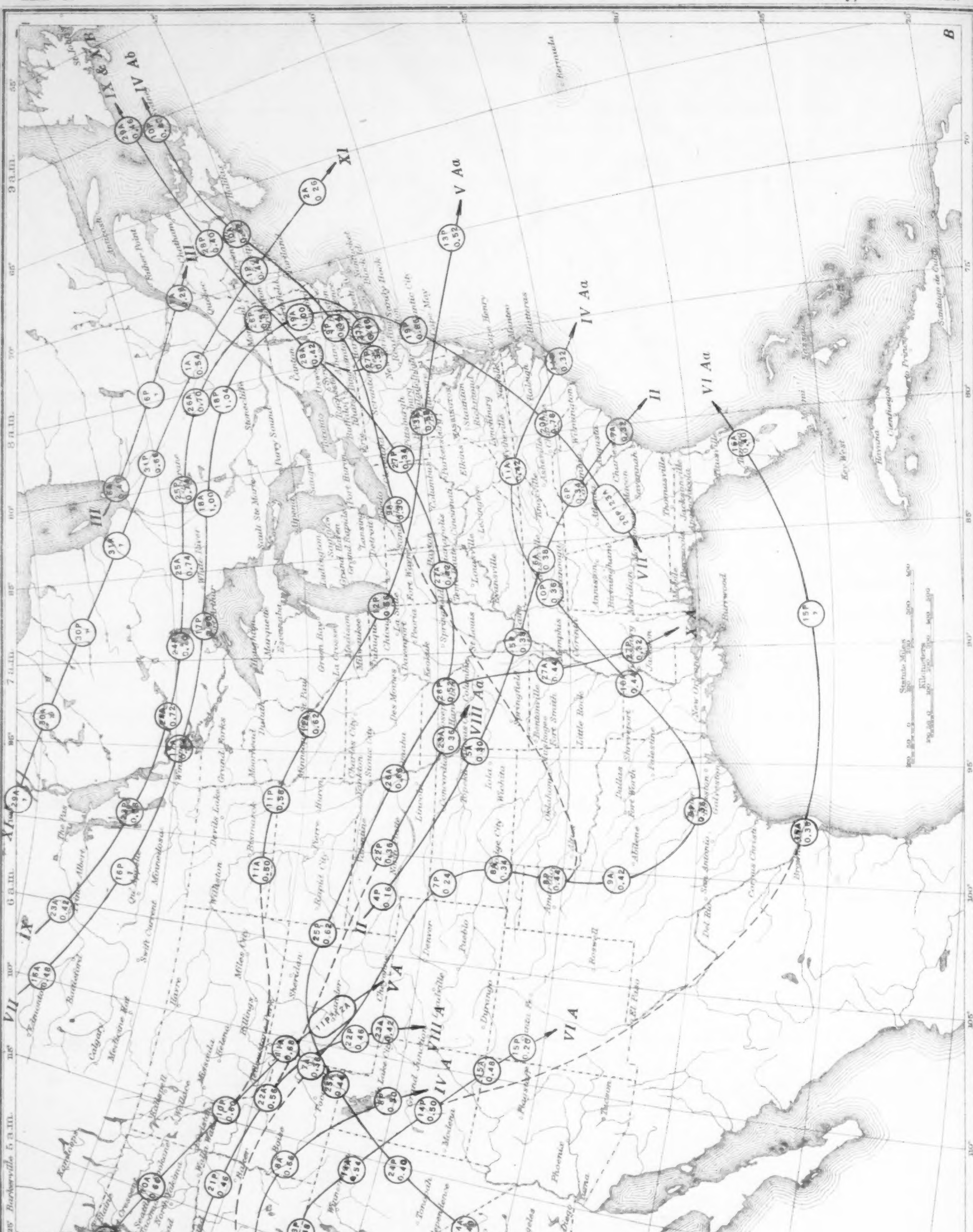


Chart III. Tracks of Centers of Low Areas, January, 1921.
(Plotted by Wilfred P. Day.)

Chart III. Tracks of Centers of Low Areas, January, 1921.

(Plotted by Wilfred P. Day.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, January, 1921.

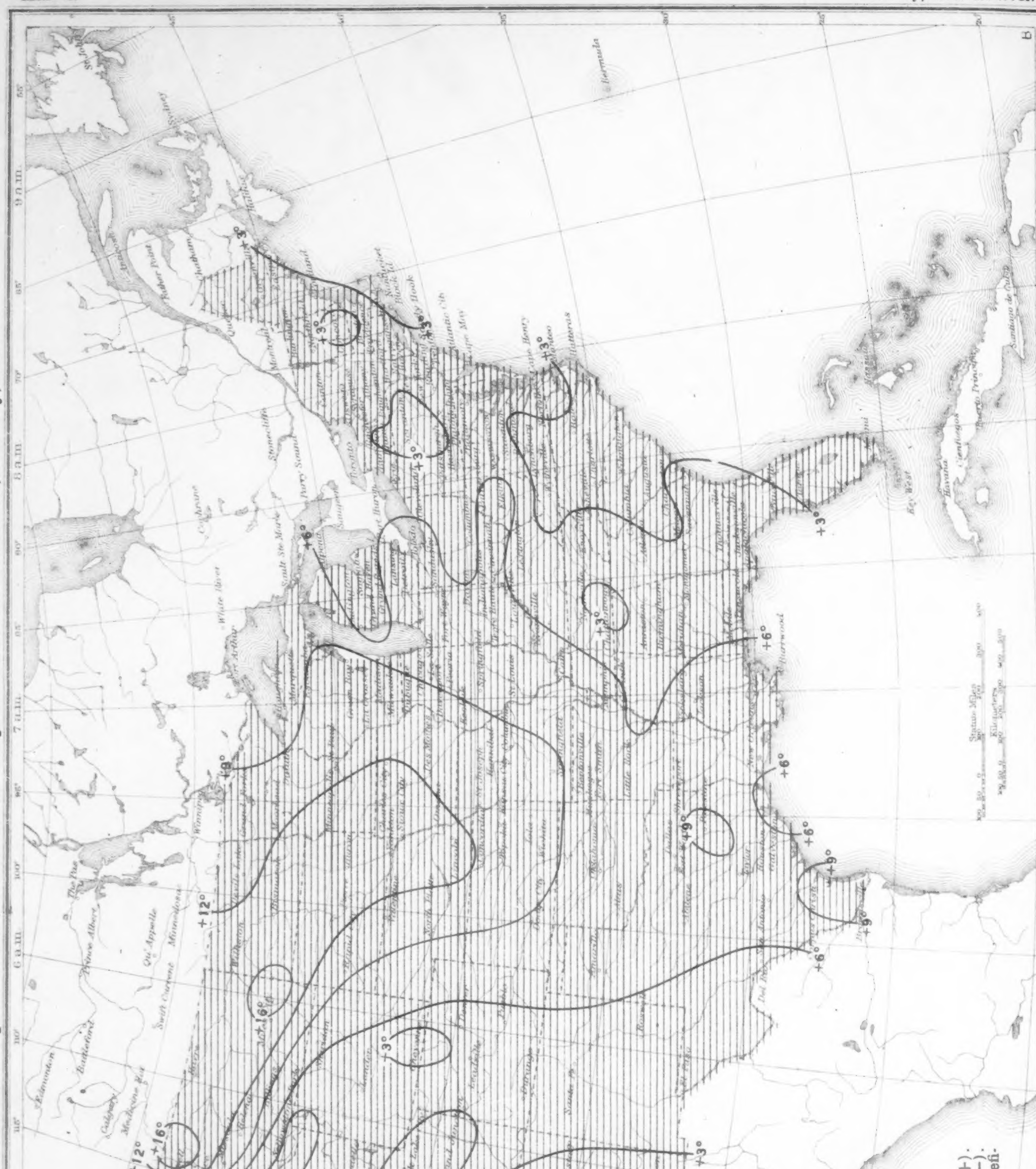


Chart V. Total Precipitation, Inches, January, 1921.

Chart V. Total Precipitation, Inches, January, 1921.

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, January, 1921.

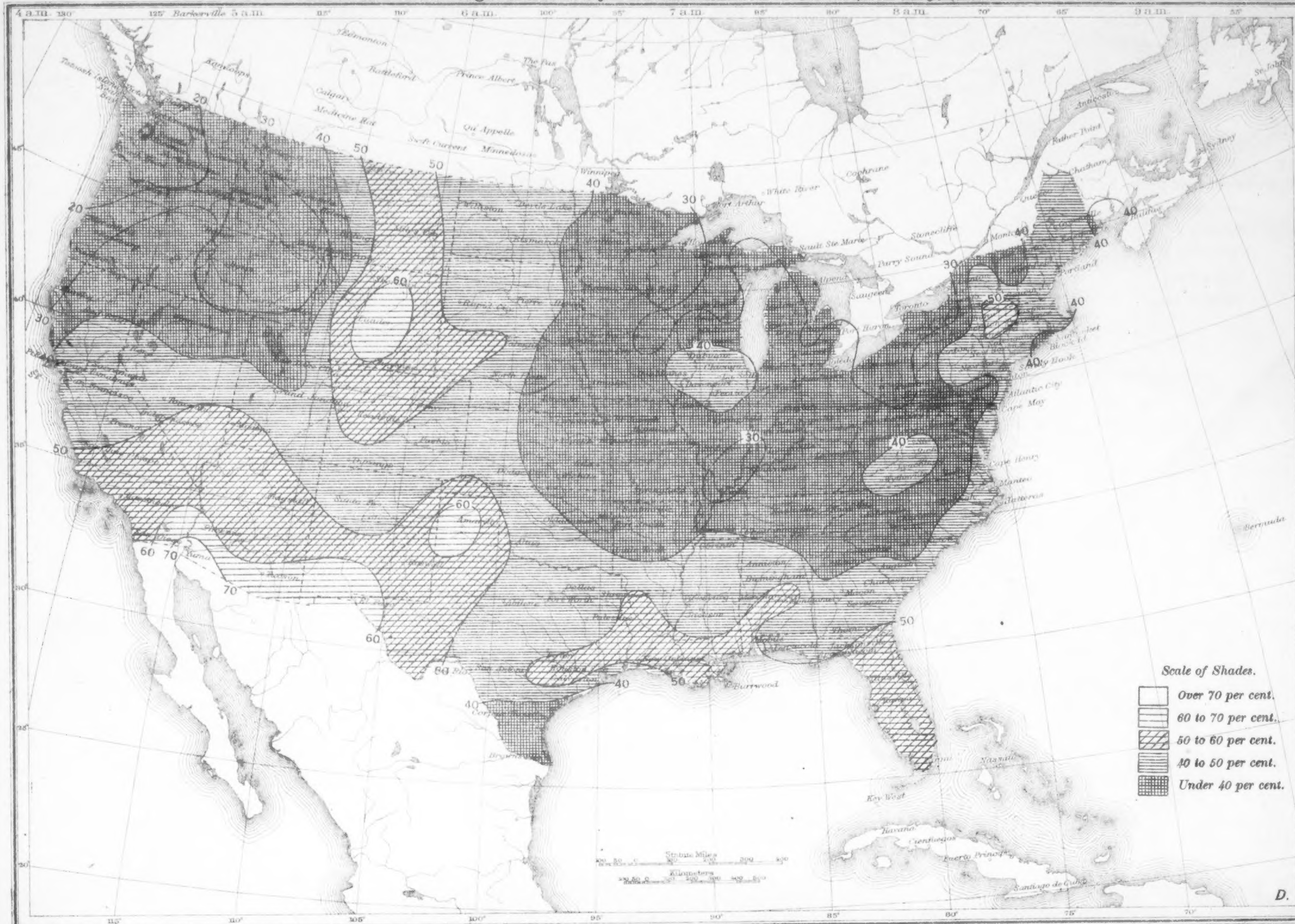


Chart VII. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, January, 1921.

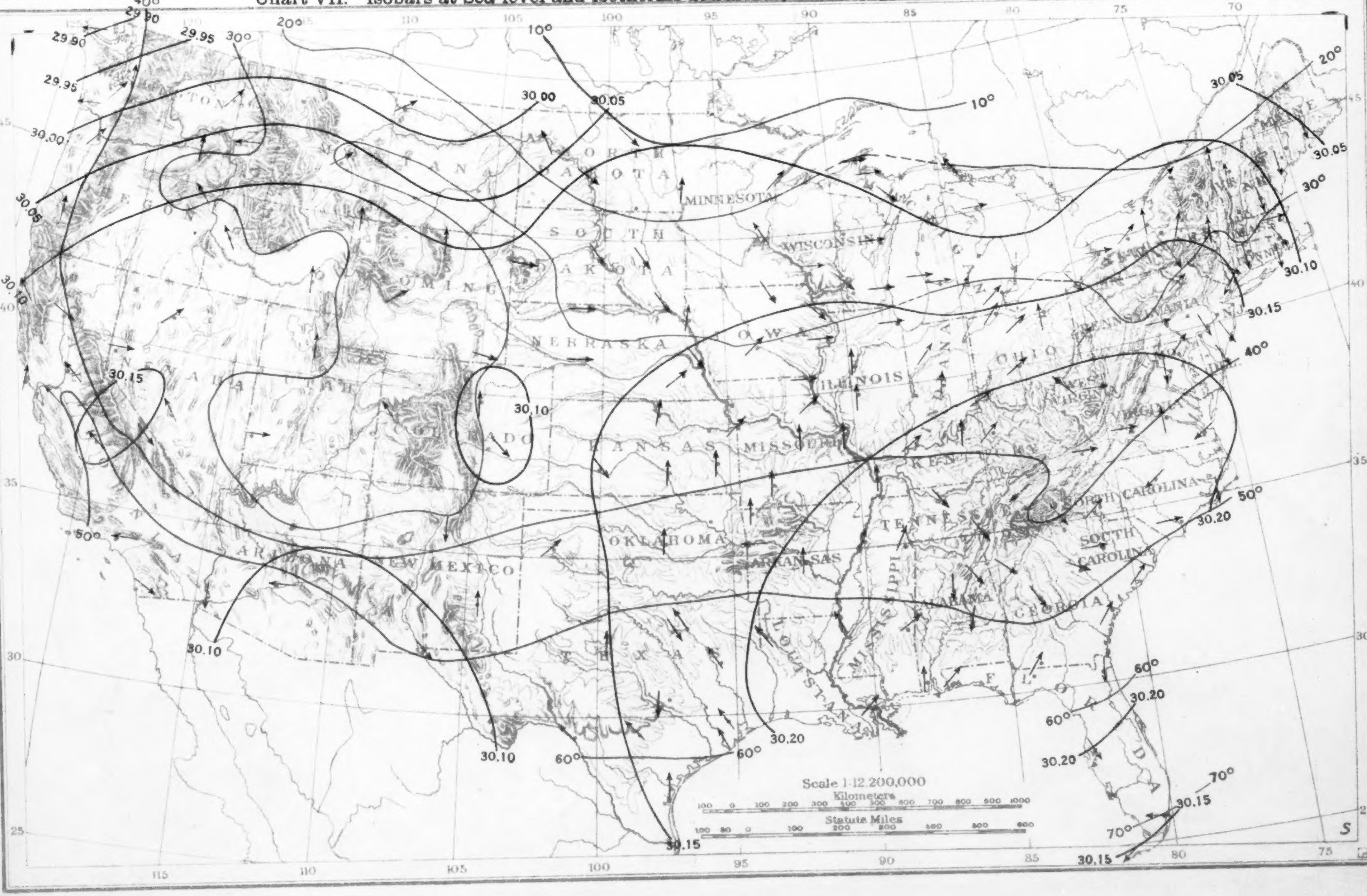


Chart VIII. Total Snowfall, Inches, January, 1921.

Chart IX. Weather Map of North Atlantic Ocean, January 10, 1921.
(Plotted by F. A. Young.)

Chart IX. Weather Map of North Atlantic Ocean, January 10, 1921.

(Plotted by F. A. Young.)

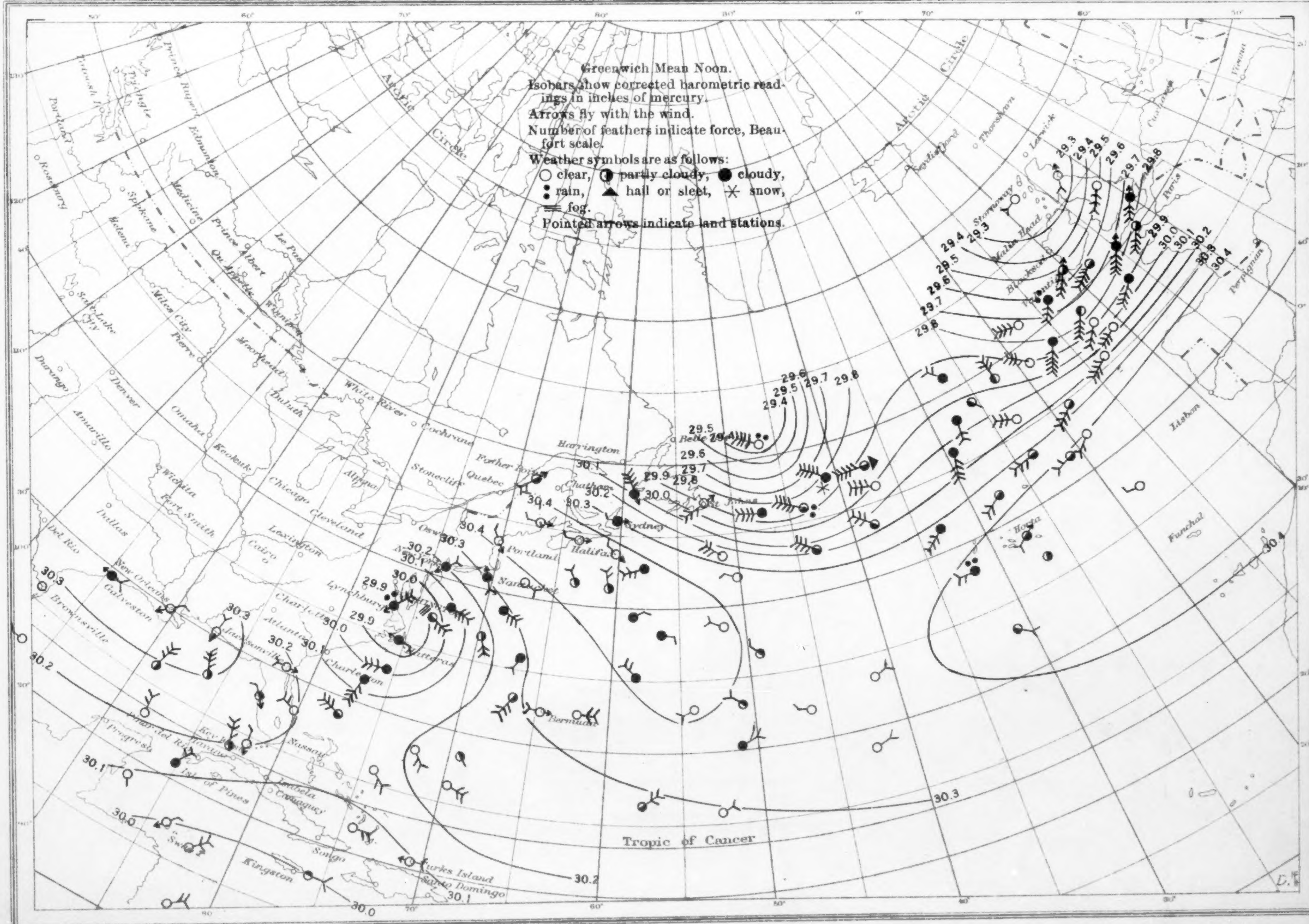


Chart X. Weather Map of North Atlantic Ocean, January 11, 1921.

(Plotted by F. A. Young.)

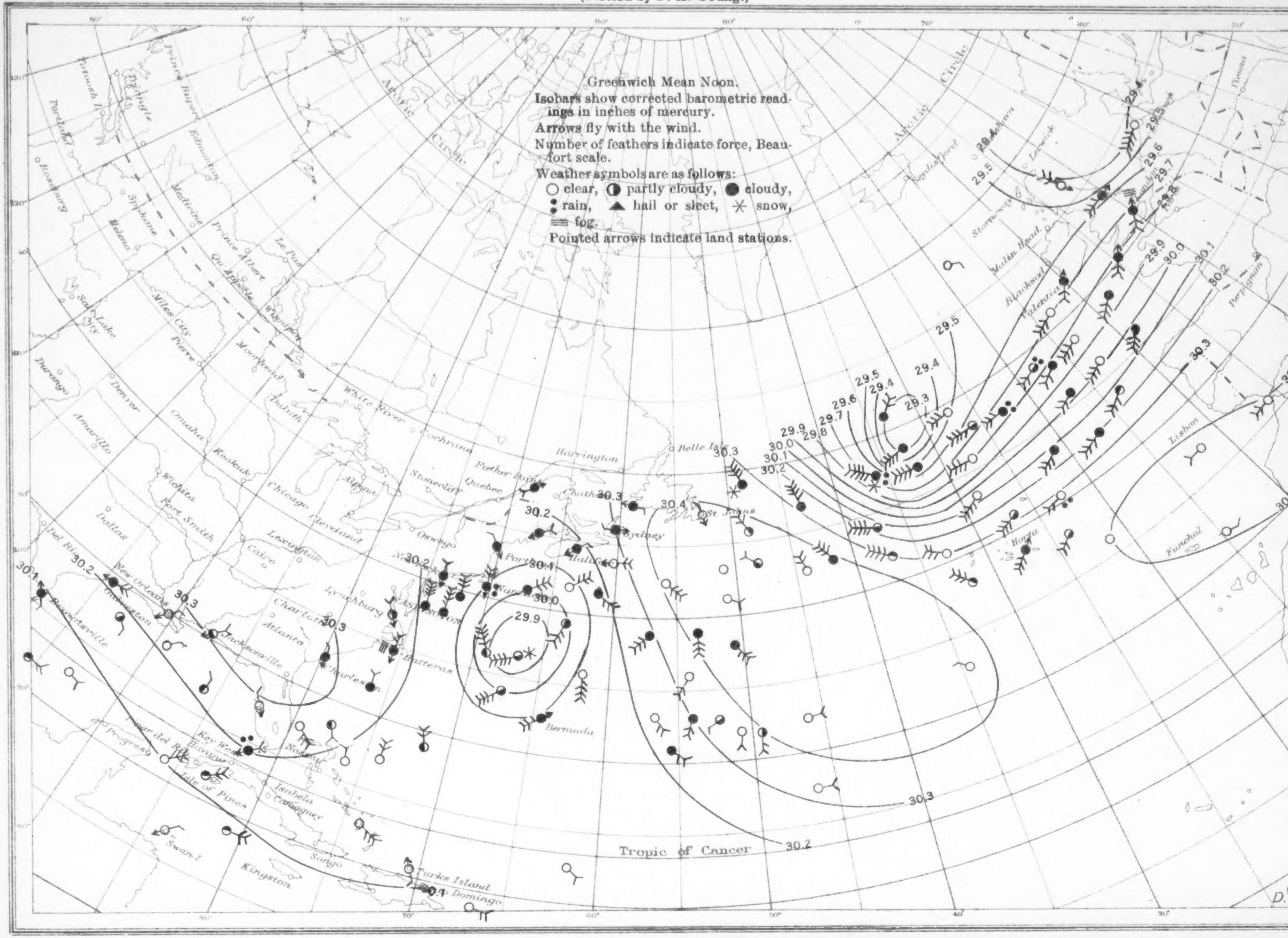


Chart XI. Weather Map of North Atlantic Ocean, January 12, 1921.

(Plotted by F. A. Young.)

Chart XI. Weather Map of North Atlantic Ocean, January 12, 1921.

(Plotted by F. A. Young.)

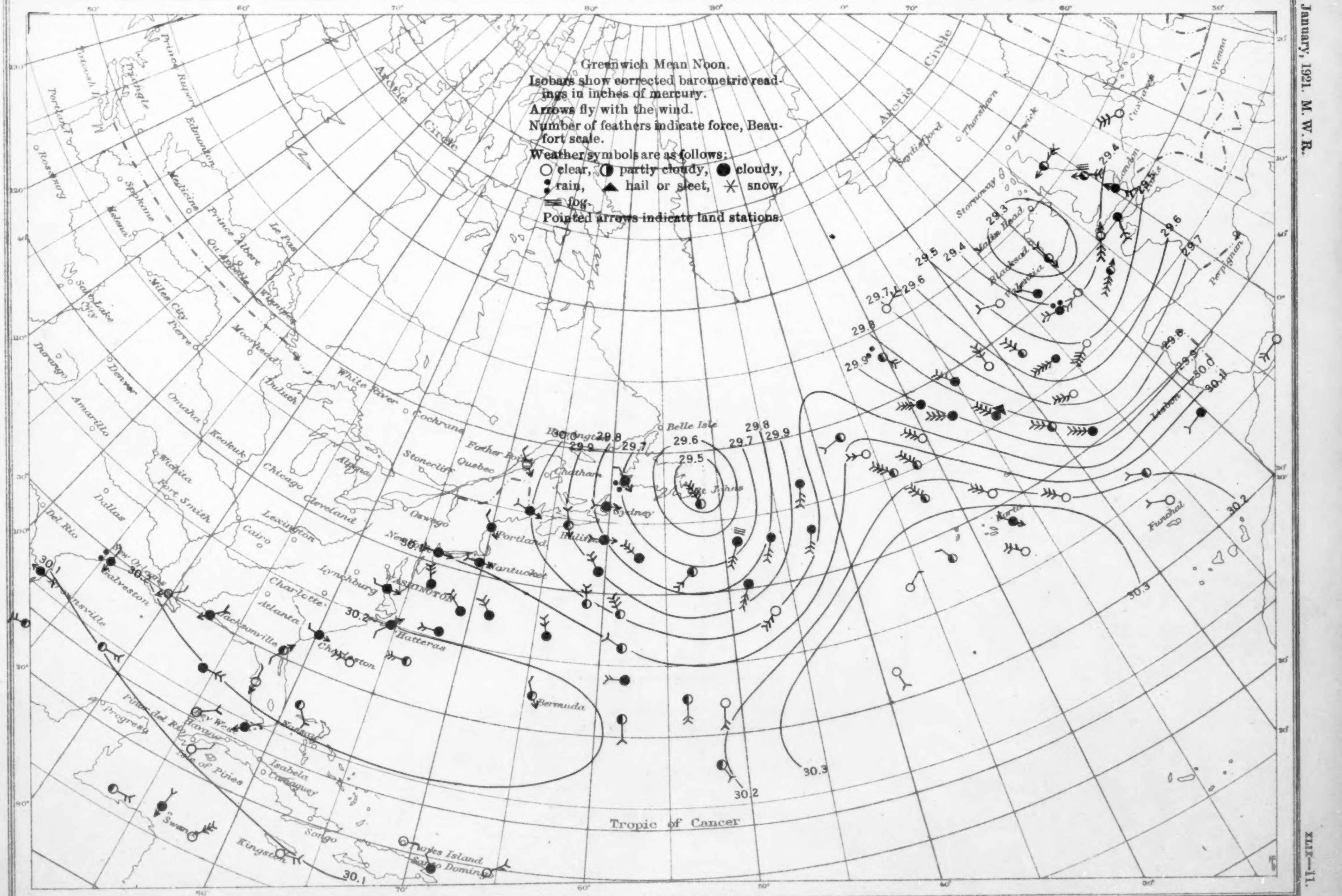


Chart XII. Weather Map of North Atlantic Ocean, January 25, 1921.

(Plotted by F. A. Young.)

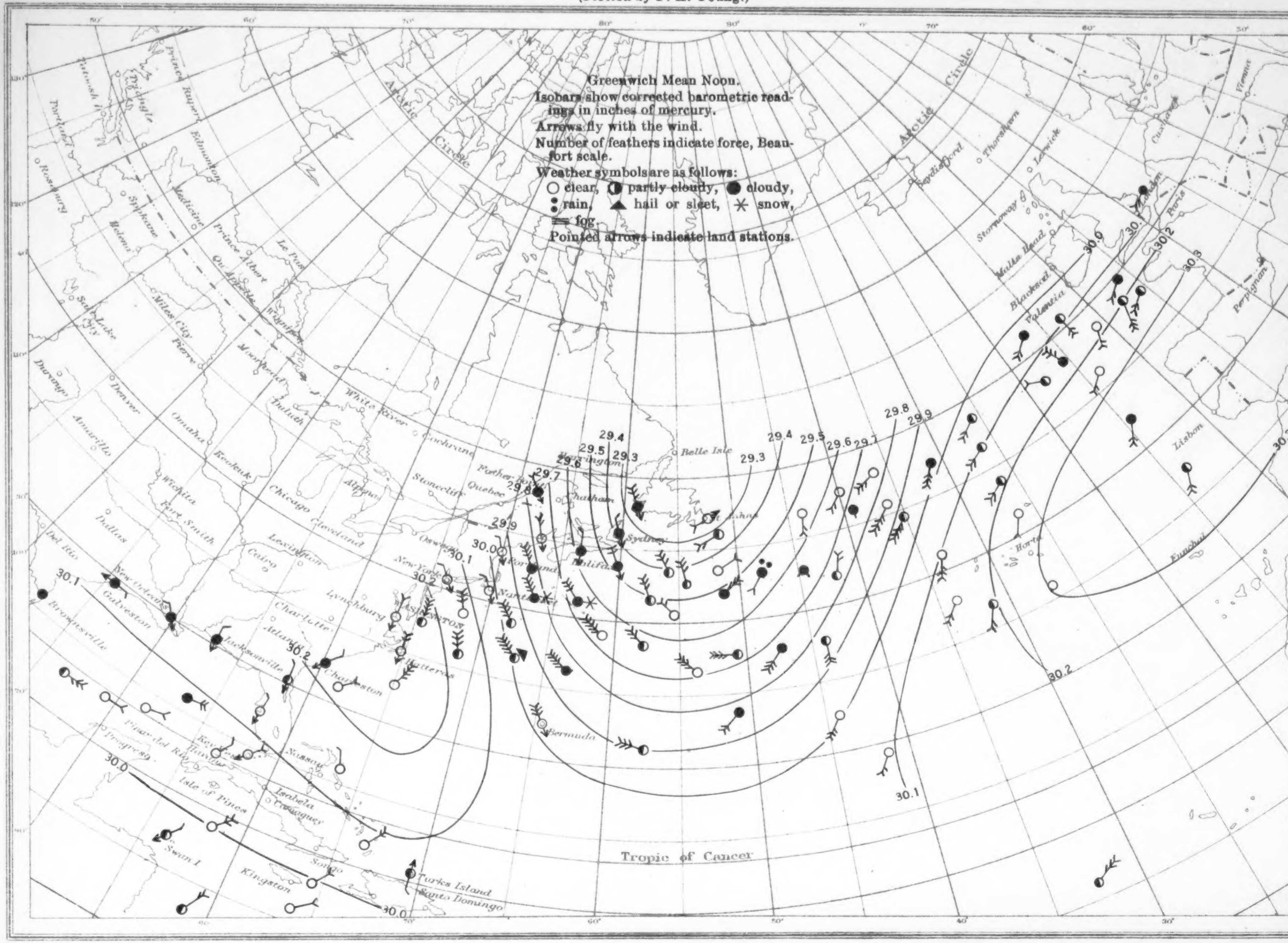
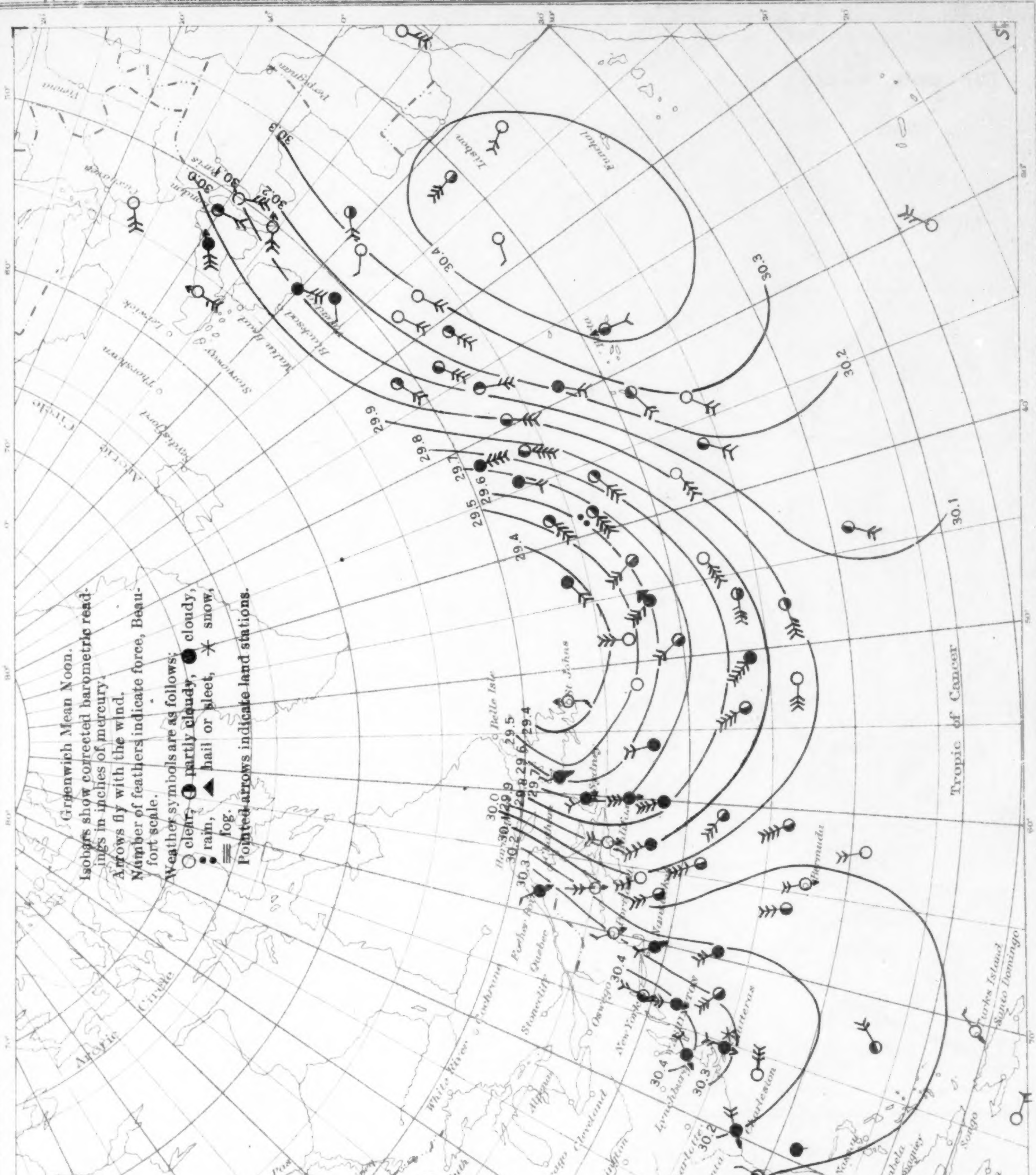
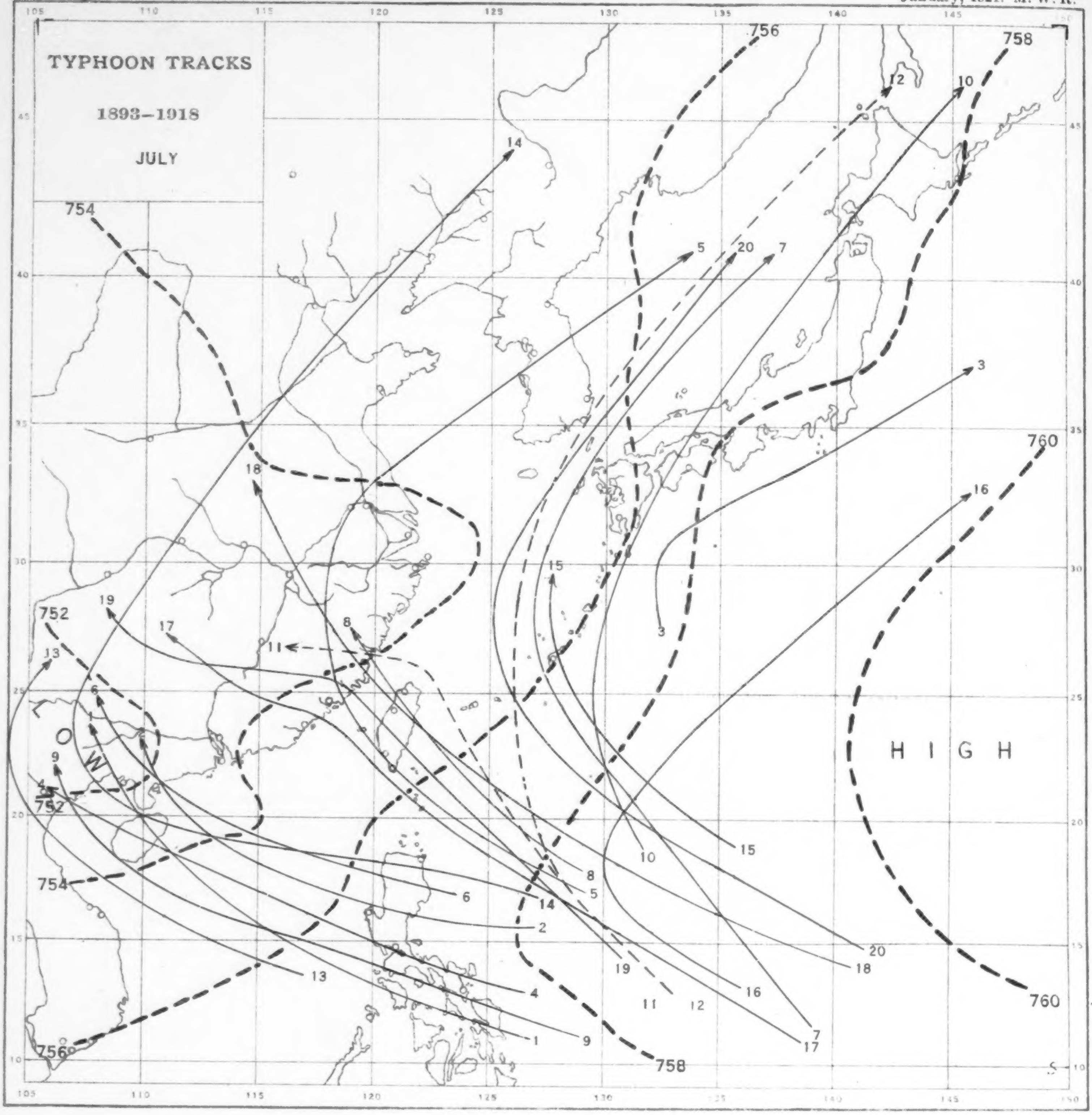


Chart XIII. Weather Map of North Atlantic Ocean, January 26, 1921.

Chart XIII. Weather Map of North Atlantic Ocean, January 26, 1921.

(Plotted by F. A. Young.)



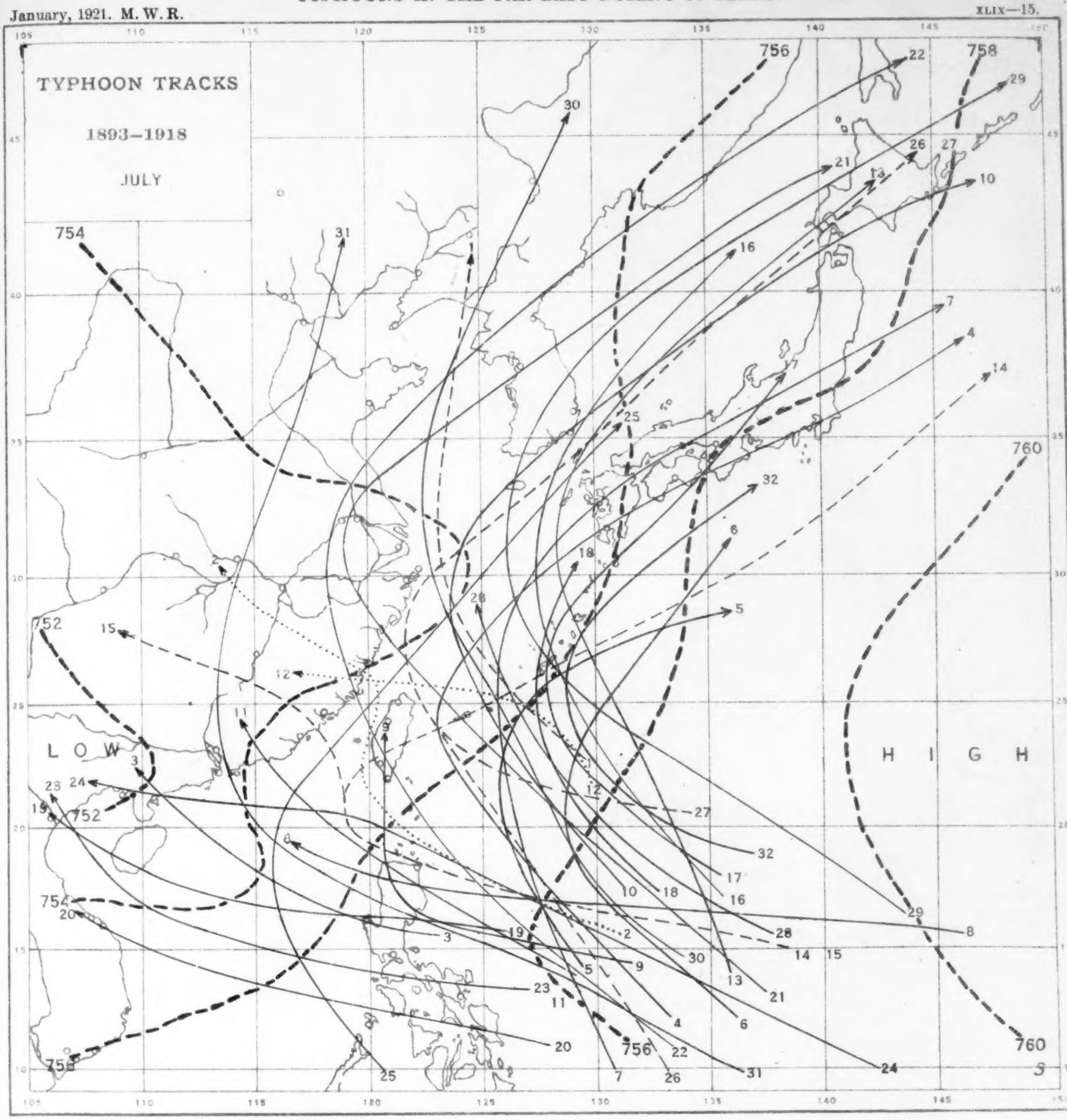


JULY.—*Three charts: 90 tracks; three or four instances every year.*

First decade: July 1-10.—20 tracks.—If we draw out these tracks to their beginning, we find that they mostly converge to one same spot, between the occidental Carolines and the southern Marianas, about latitude 10° between Yap and Guam. Starting thence, they form three bundles distinctly separated from each other: the first one runs towards WNW, crosses the Philippines and the China Sea, between the 15th and the 20th parallels and lands between Kwangtung and Annam, with a marked preference for the Gulf of Tongking. The second group travels straight towards the NW, across Formosa, and strikes the coast between Swatow and Foochow: both are usually seen to fill up on land, without returning to the Sea. The third cluster, the eastern one, follows at first, a path parallel to the second one, then recurves towards the NE, when crossing the Loochoos, and goes to sweep over the Japan Sea and Archipelago. It is very rare, during the beginning of July, to receive these dreaded visits between Chusan Is., Korea and the Gulf of Pechihli.

During the same period, the minimum has continund to grow deeper and deeper on the Continent, chiefly in northern Tongking; on the other hand, although the isobar 758mm has retired a little eastwards, the oceanic maximum continues to make itself felt over the Carolines, the Marianas and the Bonin group.

[Reproduced from Atlas of the Tracks of 620 Typhoons, 1893–1918, by Louis Froc, S. J., Director Zi-ka-wei Observatory, Zi-ka-wei–Chang-hai, 1920.]

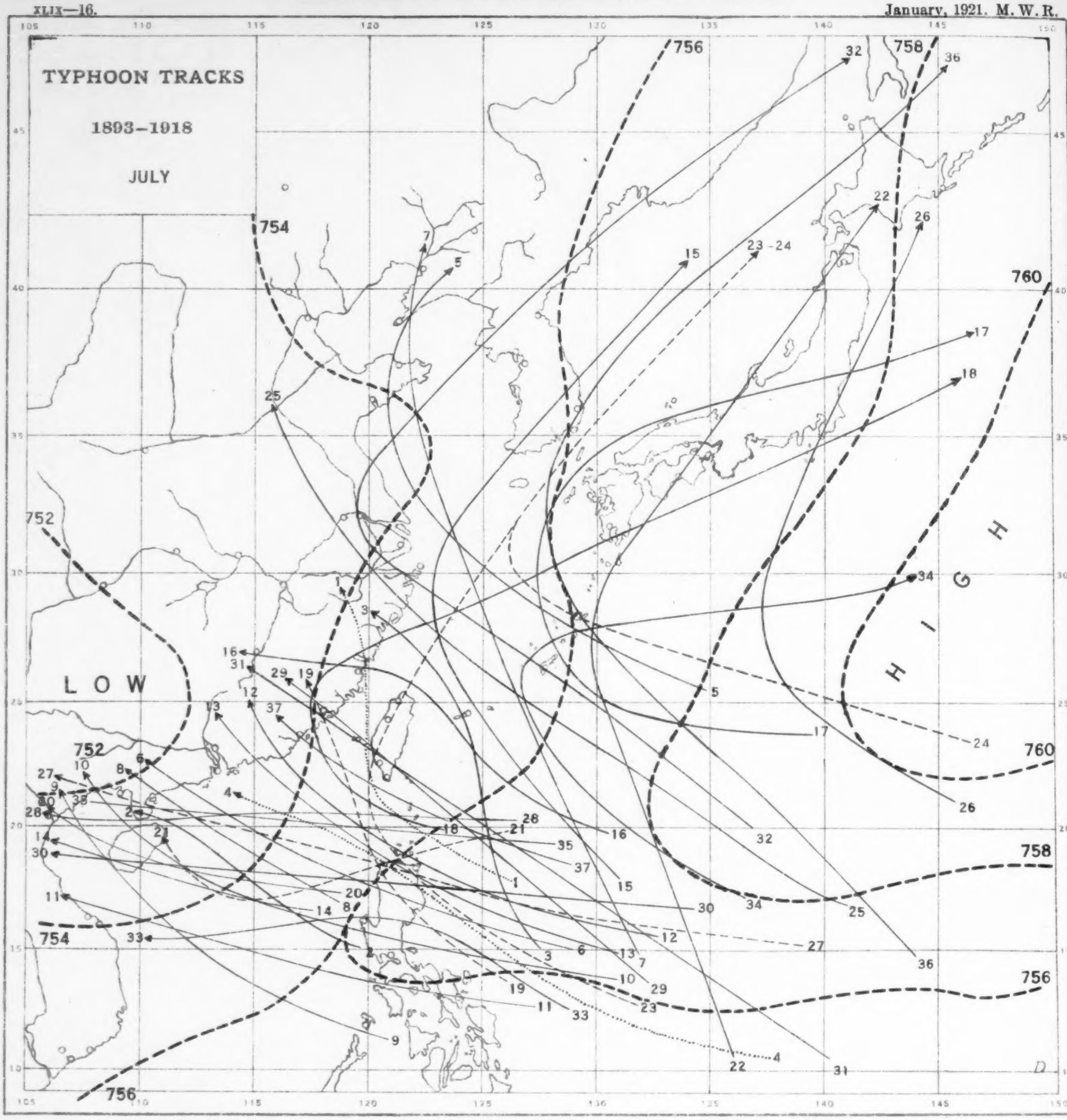


JULY.—*Three charts: 90 tracks; three or four instances every year.*

Second decade: July 11-20.—32 tracks.—The more we advance into the typhoon season, the greater is the number of the storms; the three bundles, separated during the first period of the month, are coming close together, and their lines cover a kind of *fan*, the handle of which is seen resting broadly between Yap and Guam, while the extreme edges or leaves lie down, on one side along the Loochoos and the S. coast of Japan, on the other across the China Sea, from Palawan to the coast of Annam.

Henceforth no place on the coasts of China and Japan is under shelter: at the same time there is a remarkable immunity for the China Sea, below the 15th parallel, and the Pacific between the Marianas, the Bonin group and the neighborhood of Tôkyô. The turning point of the "*parabolas*" is found, more and more frequently, in the surroundings of the Loochoos, and farther North, between the 125th and the 130th meridians. The focus of the origin rests roughly at the same place as before, between the Carolines and Marianas.

[Reproduced from Atlas of the Tracks of 620 Typhoons, 1893–1918, by Louis Froc, S. J., Director Zi-ka-wei Observatory, Zi-ka-wei–Chang-hai, 1920.]



JULY.—*Three charts: 90 tracks; three or four instances every year.*

Third decade: 21-31.—37 storms.—The most striking feature of this period, is the obstinacy with which the typhoons come repeatedly to hit Haïnan island and the Gulf of Tongking. At a time when the storms have diminished in Japan, the straight trajectories are seen to gather, to follow each other on both sides of the 20th parallel, and running, as a rule towards WNW, strike the coast between Kwang-chow-wan and Vinh in the South of the Gulf. The China Sea, to the South of the Paracels remains clear of typhoons during the middle of the month, and the Pacific, between the N. Marianas and the SE corner of Japan is remarkably free too.

Some great typhoons trace now very large paths on the Eastern and the Yellow Seas: they may recurve off the Saddles, and even farther West, across the Blue River, near Nangking and Chinkiang. Let us observe that a relatively small number of them draw the so-called "*parabola*"; the very great majority come to land, without recurving and disappear on the Continent between Thibet and the western provinces of China. A fact, rare as it may be, must not pass unnoticed: on the China Sea a few tracks are traced due West, or even (Nos. 21 and 23) in a WSW direction.

[Reproduced from Atlas of the Tracks of 620 Typhoons, 1893–1918, by Louis Froc, S. J., Director, Zi-ka-wei Observatory, Zi-ka-wei–Chang-hai, 1920.]

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JANUARY, 1921.

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* Separates to be published.

† In marine separate.